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DESIGN OF BRIDGE CONTROL CONSOLE FOR LANDING SHIP TANK (LST)

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DESIGN OF BRIDGE CONTROL CONSOLE FOR LANDING SHIP TANK (LST)

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ABSTRACT

In the Bridge Control Console, there are many equipment that must be operated in a long period repeatedly and with various obstacles faced in the middle of the sea. Therefore, a high concentration is required to avoid ship accident due to human error which is fatigue. The level of competition in shipbuilding industry increases sharply. In order for the company to survive in the midst of intense competition then the company must produce products that are reliable and have a good value in the eyes of the customer. Reliable products are products with ergonomic design or products that are developed by considering the ergonomic approach, one of them is anthropometry. Products that have a good ergonomic value will be able to increase the level of comfort in work so that the potential of human error can be reduced. In this research, Bridge Control Console design will be done by using anthropometry approach. Bridge Control Console designed in this research is expected to have good ergonomic value when operated by National Army of Indonesia (TNI) as the users. Therefore, anthropometry data used is anthropometric data of TNI which is approximated from the anthropometric data of Indonesian people. Prior to use, the data passed the process of data uniformity test and data adequacy test. After the data used is uniform and meets the minimum amount of data taken, the trial and error process to estimate the percentile of the height dimension of the TNI (165 cm) body and the result states that the percentile of the height dimension of TNI body is in percentile 25. From the trial and error, it can be known that the dimension height of TNI body (165 cm) is 25 percent of Indonesia population. Therefore, in this research, the percentile range used in the calculation is more than 25%. Before entering the Bridge Control Console design, the process of determining the design principles (minimum, & maximum) is done and then followed by determining the percentile value to be used. In this research, besides using the anthropometry approach, the Bridge Control Console designed also considers the guidance in the "Guidance Notes on Ergonomic Design of Navigation Bridge" or known as ABS (American Bureau Shipping). The Bridge Control Console design validation process obtained in this research is done by comparing each of the BCC dimensions between the results of this research and the ABS dimension.

Keywords : **Bridge Control Console, Ergonomics, Anthropometry, Data Uniformity Test, Data Adequacy Test, Design Principles, Percentiles.**

PREFACE

Thanks to the almighty Allah SWT. for his blessings and graces so that I could complete the Final Research entitled "DESIGN OF BRIDGE CONTROL CONSOLE FOR LANDING SHIP TANK (LST)". This bachelor thesis was written to meet the graduation requirements of the Bachelor Degree program in the Department of Marine Engineering - Sepuluh Nopember Institute of Technology (ITS) and Hochschule Wismar. During this bachelor thesis, I often got guidance, direction, motivation, spirit as well as help from many parties. Therefore, I would like to express my gratitude to the parties who have helped me in completing this bachelor thesis, those are :

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I realize that this bachelor thesis is not perfect, therefore criticism and suggestions are urgently needed for the improvement in the future. Hopefully, this bachelor thesis will be useful for the readers. Finally, I would like to express my gratitude.

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Author

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CHAPTER I
INTRODUCTION

1.1 Background

In a wheelhouse, there are various components which one of them is a Bridge Control Console that supports ship navigation activities during its operation. The ship usually will be operated in fairly long period and face various types of circumstances that require more concentration. Thus, in navigating the ship, the operator needs a comfortable atmosphere. It is important to prevent the ship operator to have fatigue during their operation. If the operator is tired, then the operator may not concentrate on their work which can trigger a ship accident. Therefore, an approach in designing a humane working system in Bridge Control Console referring to the aspect of ergonomics is required.

According to International Ergonomics Association (IEA) in Radjiyev et. al. (2014), Ergonomics itself is a discipline that deals with the understanding of the interaction between human beings with the other elements in a system. The relationship achieved through the application of the theory, principles, data, and methods to design an optimize human well-being and overall system performance (ABS, 2003). Ergonomic principles can also ensure the working system to be effective, convenient, safe, healthy and efficient. The design and arrangement of the equipment must be compatible with the ship operators adapted to the dimensions and role of the work functions. So that, the ongoing work activities will run as expected. In addition, the competition in the field of the shipbuilding industry in the world are increasing sharply. The human resources have to own an excellent competence to produce a product that is reliable and has more value in the eyes of consumers. Shipyard in Indonesia is a manufacturer of any ships, especially Landing Ship Tank. It still gets quite less attention to the design of the Bridge Control Console that refers to aspects of ergonomics. It can also happen because there is a lack of awareness and knowledge in designing the Bridge Control Console according to ergonomic principles.

Therefore, the researcher aims to design Bridge Control Console according to the correct ergonomic principles which is expected to be used as an input to reduce the number of accidents caused by ship operators who experience fatigue while working and also add more value to the Bridge Control Console in the ship which will be produced by the shipyard in Indonesia.

In this research, the Bridge Control Console will be developed using anthropometry approach combined with the existing constants in the Guidance Notes in Ergonomic Design of Navigation Bridges. Therefore, it is expected that the Bridge Control Console is designed to have a good level of comfort.

1.2 Statements of Problems

Based on the description above, some problems on this research are :

1. How to design a Bridge Control Console in accordance with the principles of ergonomics?
2. How to use anthropometry data to design Bridge Control Console?

1.3 Research Limitations

Problem limitations in this research are :

1. The sample or respondents in this research are Indonesians males, aged 21-47 years, from different types of tribes.
2. The equipment used in Bridge Control Console is in the Landing Ship Tanks's owned by PT. X Shipyard.
3. Bridge Control Console was designed not to discuss the problem of installation and work system details, but focus on design issues based on anthropometry data only.

1.4 Research Objectives

Based on the problems above, the objectives of this research are:

1. Knowing how to design a Bridge Control Console in accordance with the principles of ergonomics.
2. Knowing how to use anthropometry data to design Bridge Control Console

1.5 Research Benefits

This research is expected to give benefits for the various kind of parties. The benefits that can be obtained are :

1. Provide information to the shipyard about how to design Bridge Control Console according to ergonomics.
2. Reduce the risk of ship accidents that occur due to the ship's operator’s fatigue factor during the ship operation.

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CHAPTER II
LITERATURE STUDY

2.1 Definition of Ergonomics

The word 'ergonomics' comes from the Greek : *ergos*, work; *nomos*, natural law. Ergonomics is defined as the study of a design of workplace, equipment, machine, tool, product, environment, and system which takes into consideration of human being's physical, physiological, biomechanical, and psychological capabilities and optimizes the effectiveness and productivity of work systems while assuring the safety, health, and well-being of the workers (Fernandez and Marley, 1998).

The focus of ergonomics is the study of the humans' role in the safe and efficient operation of complex industrial systems and the application of ergonomic principles and data to the design of equipment and systems. The importance of the "human element" and ergonomics in maritime safety is increasingly recognized and embraced by the maritime community (ABS, 2003).

2.1.1 Ergonomic parameters

A work system is ergonomic if it fulfills the following requirements (Pheasant, 2003) :

- Functional efficiency (including productivity, task performance, etc.)
- Ease of the comfort used
- Health and safety
- Quality of working life

2.1.2 The purposes of ergonomics

The general purposes of ergonomics are:

- Improving the physical and mental health of the operator by preventing the occurrence of injury and occupational diseases, decreasing the physical and mental of workload, seeking promotion as well as job satisfaction.
- Improving the social welfare by increasing the social contact quality, as well as managing and coordinating the occupation in time. It also

improves the social security both during the period of productive age or post-productive.

- Creating the rationality of various aspects including aspect of technic, economic, anthropology and culture of each work system undertaken in order to create a high quality of work and life.

2.1.3 The benefits of ergonomics

Ergonomics has several benefits, including (Husein et. al, 2009) :

- Improving the performance, such as increasing the speed, accuracy, and safety of work, as well as reducing the energy and excessive fatigue.
- Reducing the time, training and educational fee.
- Reducing the wasted time and minimizing the equipment damage caused by human error.
- Improving the crew's comfort while working.

2.2 Definition of Anthropometry

Anthropometry is a science of measurement and application which builds the physical geometry, mass properties, and strength capabilities of the human body. The uses of anthropometry in the workplace include (Taifa & Desai, 2017) :

- To evaluate the operator's posture and the distances beween the operator and the controls.
- To determine the distance between the operator's body and the equipments around him which may become an obstacle.
- To identify the objects or elements around the operator which may limit his movement.
- To help the biomechanical analysis of forces and torque.

2.2.1 Types of anthropometry

Anthropometry is divided into two parts which are static and dynamic anthropometry. For an example, static anthropometry is measured when the body is resting or not moving while the dynamic anthropometry is measured when the body is moving (Sutalaksana, 2007). The dimensions in static anthropometry is measured linearly (straight) and performed on the surface of the body. Then, the results can be represented. The measurement on the individual should be done by using a particular method. The dynamic anthropometric measures three types of analysis, first is the skill level as an approach to understand the activity, for example to understand a person's performance. Second, the space required for working and third, the frequency of work variability.

In Figures 1 and 2, an example of an anthropometric application in the Bridge Control Console design is shown.

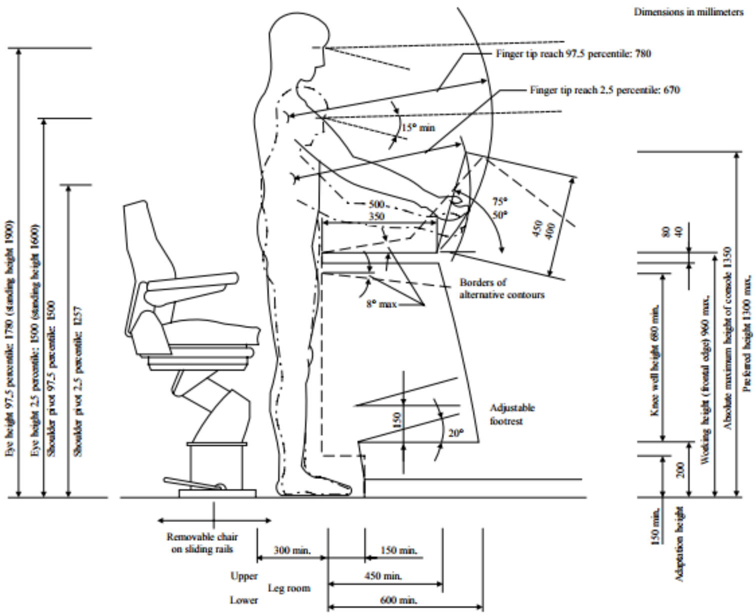


Figure 2.1 Application of Anthropometry for Bridge Control Consolein Standing Position
Source : American Bureau of Shipping, 2003

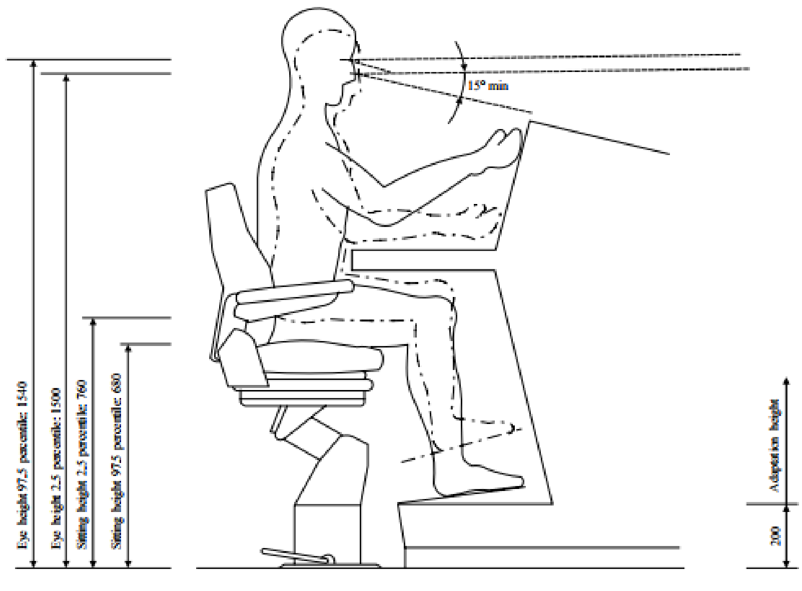


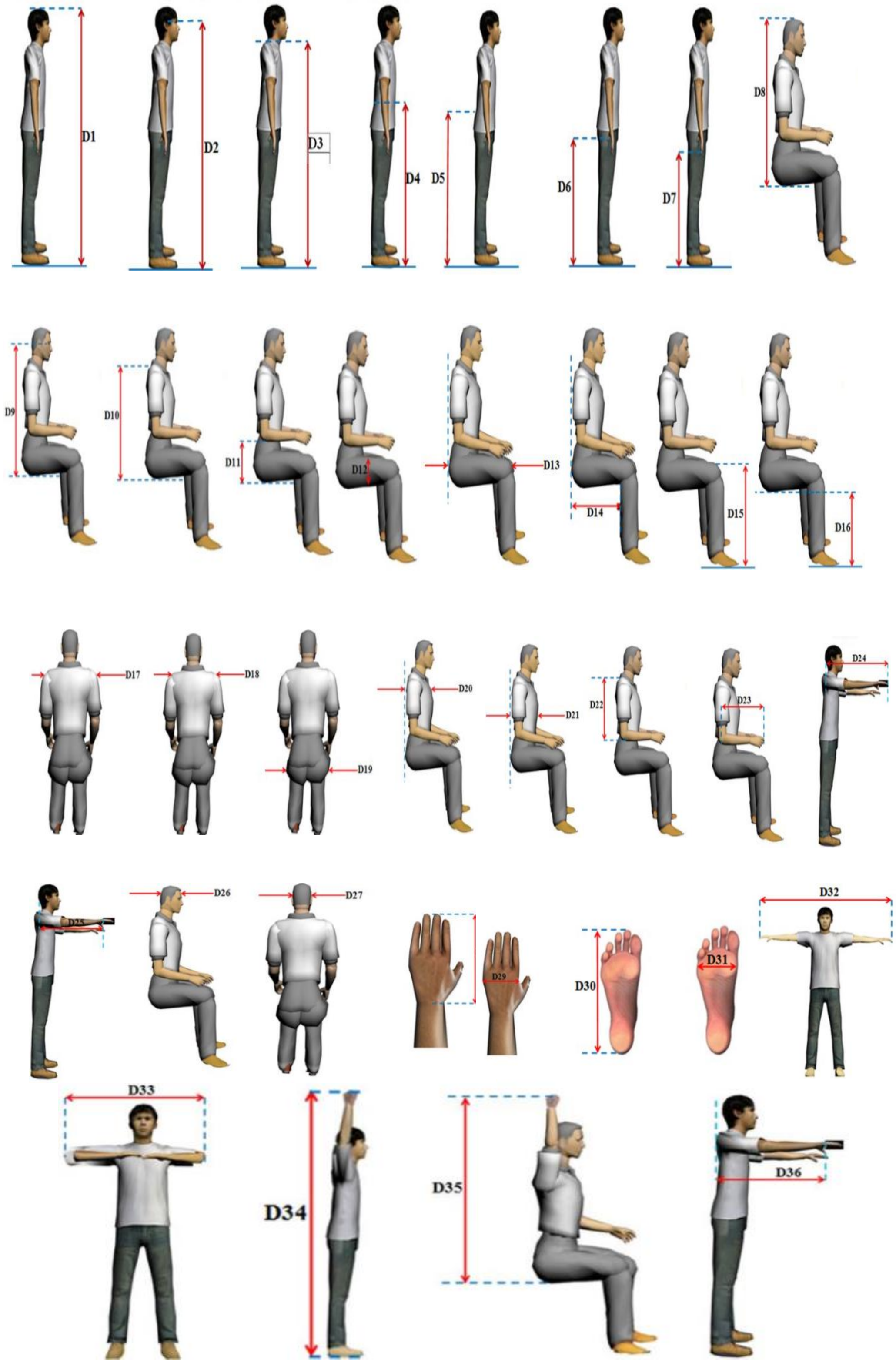
Figure 2.2 Application of Anthropometry for Bridge Control Consolein Sitting Position
Source : American Bureau of Shipping, 2003

2.2.2 Factors affecting the anthropometry

Factors which affect the dimensions of the human body are (Sutalaksana, 2007) :

- **Age** : It is known that men grow until 20 years old while women grow until 17 years old. While, their body tend to shrink when they step the age of 60 years old.
- **Gender** : Different gender will give different limb dimensions resuult. The differences in body dimensions are due to various functions.
- **Ethnicity** : Ethnicity also gives a characteristic of the body dimensions. An extreme ethnic Caucasian-European person has a different characteristic with Indonesian people whose ethnic is mongoloid. An ethniic caucasian people have a tendency of a longer body dimension compared to the ethnic mongoloid people’s body dimension.
- **Type of work or exercise** : A basic nature of human muscle, in which when a person often works out, he will have a bigger muscle compared to a person who is rarely work out. For example, the dimensions of a factory worker, the dimensions of a bodybuilder and so on.

2.2.3 Dimensions in anthropometric measurements


D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
D11
D12
D13
D14
D15
D16
D17
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D19
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D21
D22
D23
D24
D26
D27
D29
D30
D31
D32
D33
D34
D35
D36

Figure 2.3 Dimension of Anthropometry
Source : www.antropometriindonesia.org, 2013

1. **The height of body (D1)** : The vertical distance from the floor to the top of the head.
2. **The height of eyes (D2)** : The vertical distance from the floor to the outside of the right eye corner.
3. **The height of shoulder (D3)** : The vertical distance from the floor to the top of the right shoulder (acromion) or the tip of the right shoulder bone.
4. **The height of elbow (D4)** : The vertical distance from the floor to the lowest point in the right corner of the elbow.
5. **The height of hips (D5)** : The vertical distance from the floor to the right hip.
6. **The height of metacarpals (D6)** : The vertical distance from the floor to the right bone or right hand knuckle (metacarpals).
7. **The height of fingertip (D7)** : The vertical distance from the floor to the right middle finger (dactylion).
8. **The height of body in sitting position (D8)** : The vertical distance from the pedestal to the top of the head.
9. **The height of eyes in sitting position (D9)** : The vertical distance from the pedestal to the outside of the right eye angle.
10. **The height of shoulder in sitting position (D10)** : The vertical distance from the pedestal to the top of the right shoulder.
11. **The height of elbow in sitting position (D11)** : The vertical distance from the pedestal to the bottom of the forearm of the right hand.
12. **The thickness of thigh (D12)** : The vertical distance from the pedestal to the top of the right thigh.
13. **The length of knee (D13)** : The horizontal distance from the back of the buttock (hip) to the front of the right leg knee.
14. **The length of popliteal (D14)** : The horizontal distance from the back of the buttock (hip) to the back of the right knee.
15. **The height of knee (D15)** : The vertical distance from the floor to the right kneecap.
16. **The height of popliteal (D16)** : The vertical distance from the floor to the popliteal corner located below the thigh, at the back of the right leg knee.
17. **The width of shoulder (D17)** : The horizontal distance between the outermost side of the left shoulder and the outer side of the right shoulder.

18. **The width of upper shoulder (D18)** : The horizontal distance between the upper right shoulder and the left upper shoulder
19. **The width of hip (D19)** : The horizontal distance between the outer side of the left hip and the outer side of the right hip.
20. **The thick of chest (D20**) : The horizontal distance from the back of the body to the chest.
21. **The thick of stomach (D21)** : The horizontal distance from the back of the body to the most prominent part of the abdomen.
22. **The length of upper arm (D22)** : The vertical distance from the bottom of the right forearm to the top of the right shoulder.
23. **The length of forearm (D23)** : The horizontal distance of the forearm measured from the back of the right elbow to the tip of the middle finger.
24. **The length of the range of hands forward (D24)** : The distance from the top of the right shoulder (acromion) to the tip of the middle finger of the right hand with the elbow and right wrist straight.
25. **The length of shoulder-grip hand forward (D25)** : The distance from the top of the right shoulder (acromion) to the center of the cylinder rod is grasped by the right hand, with the elbow and the wrist straight.
26. **The length of head (D26)** : The horizontal distance from the front of the forehead (the center between the two eyebrows) to the center of the head.
27. **The width of head (D27)** : The horizontal distance from the left side of the head to the right side of the head, just above the ear.
28. **The length of hand (D28)** : The distance from the folds of the wrist to the tip of the middle finger of the right hand with the position of the hand and all the fingers straight and open.
29. **The width of hand (D29)** : The distance between the two outer sides of the four right hand knuckles is positioned straight and tightly.
30. **The length of feet (D30)** : The horizontal distance from the back of the feet (heel) to the very end of the right toe.
31. **The width of legs (D31)** : The distance between the two outermost sides of the foot.
32. **The length of the arm stretch to the side (D32)** : The maximum distance of the middle finger of the right hand to the tip of the middle finger of the left hand.
33. **The legth of elbow strength (D33)** : The distance measured from the tip of the elbow of the right hand to the tip of the elbow of the left hand.

34. **The height of hand grip up in a standing position (D34)** : The vertical distance from the floor to the center of the cylinder rod (center of a cylindrical rod) grasped by the right hand palm.
35. **The height of hand grip up in a sitting position (D35)**: The distance from the chair base to the cylindrical rod center.
36. **The length of handgrip forward (D36)** : The distance measured from the back of the right shoulder (scapula) to the center of the cylinder rod grasped by the right hand palm.

2.2.4 Percentile in anthropometry

The anthropometric measurement of each person is being compared to the values of the general population observed which the result is then expressed in the form of percentiles. Percentile is defined as a set of divisions which produces 100 equal parts in a series of continuous values. (Last, 1988) Thus, a person with the height above the 95th percentile is taller than 95% of all persons in a series. The smallest value of the measurement is usually associated with the 5th percentile of female, and the largest value of the measurement is usually associated with the 95th percentile male.

Percentiles are the statistical values of variables distribution transferred into a hundred scale. The population observed is divided into 100 percentage categories, ranked from the least to the highest, concerning some specific types of body measurements. The first percentile of any height indicates that 99 percent of the population would have the heights of greater dimensions than that. Similarly, a 95th percentile height would indicates that only 5% of the population observed would have greater heights and that 95th percent of the body population would have the same or less height. The 50th percentile value represents closely the average which divides the whole study population into two similar halves with one half is higher than the avarage value and another half is lower than the average value.

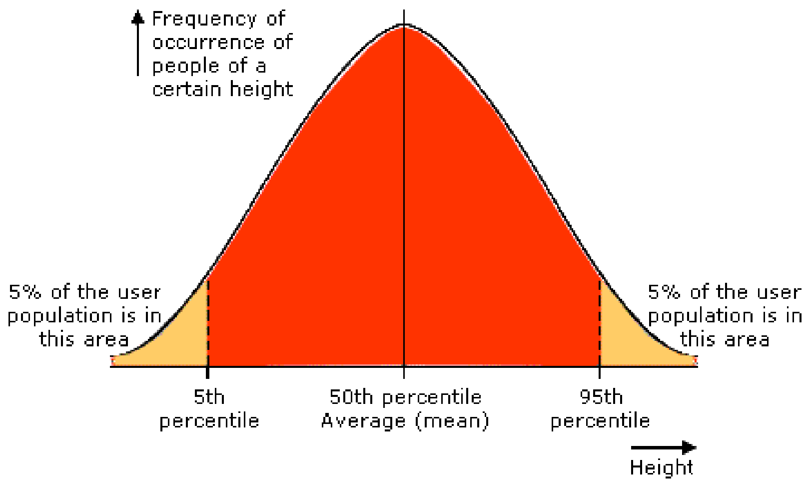

Figure 2.4 Percentile Graph
Source : www.ergonomics4schools.com

A design which used ergonomic principles can use anthropometric data by using three different methods. The first method is by taking the smallest to the largest percentile range such as from the 5th percentile to the 95th percentile, for example is the design of the operator's chair of Bridge Control Console which is adapted from the popliteal height. The second is the use of extreme percentile limits. The lower percentile is the 5th percentile, while the upper percentile is the 95th percentile, such as the length of a chair handrest which can accommodate a person who has long arm dimension and the height of the Bridge Control Console that can accommodate people who have a short shoulder dimension.

Here is a formula to calculate the value by using a specified percentile amount (Wignjosoebroto, Sritomo).

$$X = \bar{X} + Z \, x \, S \qquad \text{Equation 2.1}$$

Where,

$\boldsymbol{X}$ = The Value searched
$\boldsymbol{\bar{X}}$ = The average value of the dimensions after the data uniformity test and the data adequacy test
$\boldsymbol{Z}$ = The inverse value of the normal distribution based on the specified percentile
$\boldsymbol{S}$ = The standard deviation dimension after the data uniformity test and the data adequacy test

2.2.5 Procedure in anthropometry

Research on a workstation design is based on anthropometry, therefore it requires the following steps:

- Determining the population of operators who will use the designed workstation.
- Measuring the body dimensions of the operator in which the population has been determined before.
- Determining the percentage of the number of operators from the workstation.
- Determining the percentile of workstation to be designed.
- Determining the modifications of the data taken because the different thickness of the respondents' clothes during the anthropometric measurements.
- Conducting a simulation to test the designed workstation

2.3 Testing The Data

Anthropometric data is obtained before used and further, the processing will pass through several tests to ensure that the data is appropriate to be used as an input in the design. The tests conducted are data uniformity test and data adequacy test.

2.3.1 Data uniformity test

Fernando, 2013 states that the state of the system is always changing and cannot be continuously maintained in the same fixed state. Changes that occur are still acceptable if the changes are within the acceptable limits. Therefore, it is necessary to test whether the system changes are still within the acceptable limit or not, that is through data uniformity test. The data uniformity test is performed to find out whether the data obtained from a system, uniform or not. Here are the steps in performing the data uniformity test :

1. Calculating the average data

$$\bar{X} = \frac{\sum_{i=1}^{N} X_i}{N} \qquad \text{Equation 2.2}$$

Where,
$\bar{X}$ = average
X_i = the value of the data to-i
N = amount of the data

2. Calculating the standard deviation of the data

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N} (X_i - \bar{X})^2}{N-1}} \qquad \text{Equation 2.3}$$

Where,
σ = standard deviation sample
X_i = the value of the data to-i
$\bar{X}$ = average
N = number of samples

3. Specifies the Lower Control Limit (LCL) and Upper Control Limit (UCL)

$$LCL = \bar{X} - 3\sigma \qquad \text{Equation 2.4}$$
$$UCL = \bar{X} + 3\sigma \qquad \text{Equation 2.5}$$

2.3.2 Data Adequacy Test

Data adequacy test is conducted to determine whether the amount of the data taken is a sufficient amount of data that should be taken or not. The following is a formula used in the data adequacy test :

$$N' = \left[\frac{Z.S}{\bar{X}\,k}\right]^2 \qquad \text{Equation 2.6}$$

Where,
N' = the number of observations (data) that should be taken
Z = Index level of confidence (95% of confidence level = 2)
S = standard deviation of the data
$\bar{X}$ = the average data after uniformity
k = error rate (5%)

The data taken is enough if N (amount of the data taken) is greater than or equal to N' (the amount of the data that should be taken). Conversely, if N is smaller than N', then the data taken is not enough so it is necessary to add the amount of the data taken.

2.4 Engineering System Design Process

The design of an instrument is included in the engineering method, thus the designing steps will follow the engineering method. Merris Asimov explains that engineering design is an activity with a specific purpose towards the goal of the fulfillment of human needs, especially those that can be accepted by the technological factors of our civilization. From the definition, there are three things that must be considered in the design those are:

1. Activity with a specific purpose.
2. Aims at meeting human needs.
3. Based on technological considerations.

An engineering system design process can be seen as a sequence of the following stages (Ventura) :

- **Analysis** : A process of partitioning or decomposing any system into its sub-system and parts to determine their separate and collective nature, proportion, functions, relationships, etc.
- **Synthesis** : A process of integrating a collection of sub-systems to create a system with emergent properties.
- **Evaluation** : A process of assesing the degree to which a solution satisfies the goals that were originally stated.

2.4.1 Approach to design workstation

In designing new workstations or modifying old workstations, there are some obstacles such as financial factors and technological factors that may be faced. In this case, the examples are flexibility, space availability, environment, the frequency of tools used, work sustainability and population targets. Therefore, some considerations are needed to retrieve the anthropometry data, equipment layout during work position, body coverage, appearance and space as well as the interface between operator and workstation. In addition, the design of workstations must begin to identify the variability of the user population based on the user's ethnicity, gender, age and others.

According to Das and Sengupta (1993), the systemic approach in determining the dimensions of workstations can be done in the following steps:

1. Identifying the variability of the workstation user population based on the ethnic, gender and age.
2. Obtaining the anthropometric data which is related to the user population.
3. In anthropometric measurements, it is necessary to consider the clothing, shoes and normal position of the user.
4. Determining the height range of the main job. Provision of chairs and workbench that can be adjustable, so that the operators are enable to work whether by sitting or standing.
5. The layout of hand tools and the control should be within the range of the optimum range.
6. Placing the appropriate display so that the operator can see the object with the right view and comfort.
7. A review of the design of the work station periodically.

2.4.2 Objective of integrating ergonomics in engineering design

Ergonomics focuses as well as represents the operator and maintainer needs and requirements throughout the productive age of the systems. It aims to minimize the human error, by maximizing the human and the total system safety and effectiveness. This can be accomplished through:

1. The application of ergonomic principles, guidelines and criteria
2. Conducting an appropriate analyses and solicitation of operator or maintainer input to derive the task requirements and needs.
3. The application of a logical, practical, human-system interface design process.

2.5 Bridge Control Console Arrangement

In order to ensure the convenience of the operator while performing the task, the workstation must be able to present the basic information required by the operator. Here, the principle of ergonomics is needed in order to support it. The information system and control possibilities should be made available to the workstations in such a way that the tasks at each of these stations can be efficiently carried out.

Figure 2.5 Bridge Control Console
Source : www.km.kongsberg.com

According to IACS Rec 95 (2011), workstation is a workplace at which one or several tasks constituting a particular activity are carried out, designed, arranged and located as required to provide the information, systems and equipment required for safe and efficient performance of dedicated tasks and bridge team co-operations. IACS points A 5.17.1 – A 5.17.1 classifies the workstations in Bridge Control Console :

A 5.17.1 *Workstation for monitoring : A workstation facilitating equipment and a commanding view for observation of the ship's heading and speed, the waters and traffic, incorporating means as required for route monitoring, used by the watch officer, assistant navigator or pilot as required for efficient bridge team operations.*

A 5.17.2 *Workstation for navigating and manoeuvring: A workstation with commanding view used by navigators when carrying out route monitoring, traffic surveillance, course alterations and speed changes, and which enables monitoring of the safety state of the ship.*

A 5.17.3 *Workstation for communication : A workplace for operation and control of equipment for Global Maritime Distress and Safety System (GMDSS), and shipboard communication for ship operations under normal conditions and emergency situations.*

A 5.17.4 *Workstation for safety operations : A workplace dedicated for organisation and control of internal emergency and distress operations providing easy access to external and internal communication and information related to the safety state of the ship.*

A 5.17.5 *Workstation for docking : Workplace on bridge wings providing the field of vision and information required for controlling the manoeuvring of a ship alongside a berth, tug operations and mooring operations.*

A 5.17.6 *Workstation for manual steering : A workplace providing the field of vision, indicators and equipment required for steering the ship manually by a helmsman in accordance with orders received from the navigator responsible for bridge operations.*

A 5.17.7 *Workstation for planning and documentation : A workplace equipped for planning the route(s) of the complete voyage from departure to destination and documenting bridge operations during the voyage.*

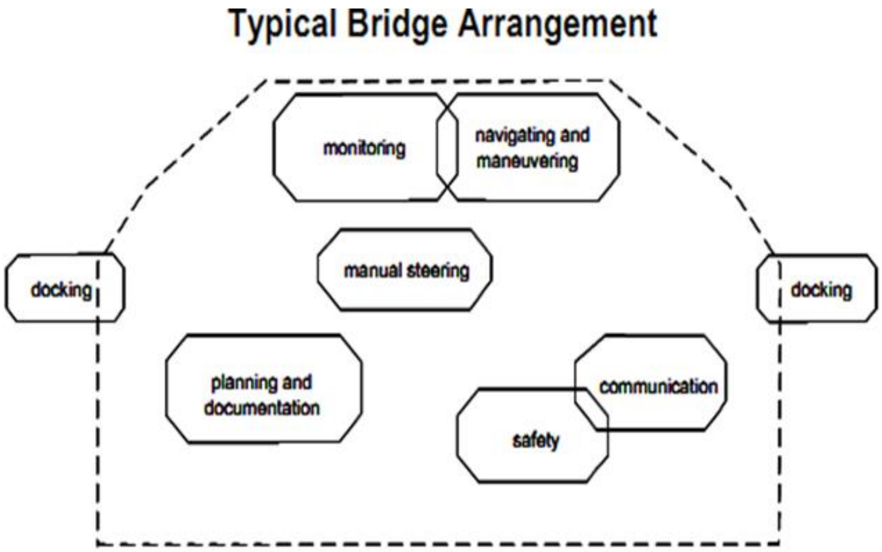

Figure 2.6 Typical Bridge Arrangement
Source : American Bureau of Shippping, 2003

2.6 Definition of Landing Ship Tank

Landing Ship Tank usually called as "big slow targets," "long slow targets," "large stationary targets (when thrown)," green dragons "(in tropical greenery), or" man-made whales. It is one of the largest warships which is a particular type used during the second world war to transport tanks and requirements of the war as well as to unforeseen rules such as the ability to invade foreign shores so that it can attack the area that is less well preserved.Although it does not work to attack directly to the enemy, the ship is still equipped with combat equipment for self-protection which is in operation is not regulated through the bridge control console located in the wheelhouse. Landing Ship Tank has the advantage of being able to dismantle its cargo facilities using the help of dock facilities such as cranes.

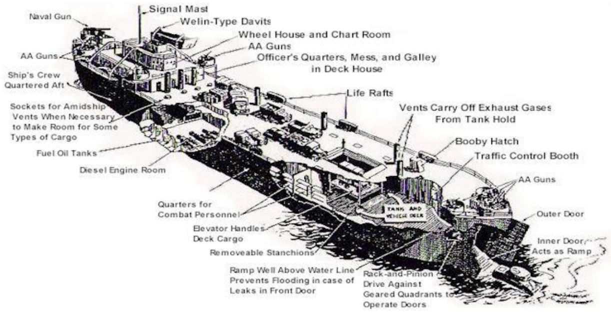

Figure 2.7 Landing Ship Tank during World War II
Source : www.landingship.com

A total of 3 units of Landing Ship Tank ship with a length of 120 meters have been ordered by TNI-AL to the national shipyard namely PT.X.The plan of these vessels will be transporting vehicles such as the Main Battle Tank (MBT) Leopard 2 operated by TNI-AD.The researcher takes the object as a research material on this final project.

Figure 2.8 Landing Ship Tank AT-4
Source : www.jakartagreater.com

CHAPTER III
METHODOLOGY

This chapter describes the steps taken in this research so that this research can run systematically and in accordance with the target to be achieved. This research is divided into 4 major steps namely **Step 1** : Problem Identification & Analysis, **Step 2** : Collecting and Data Processing, **Step 3** : Design and Analyse the results, and **Step 4** : Conclusions and Recommendations. In the implementation of this research, these four steps are divided into more detailed steps that serve as the basis of reference to complete this research. The steps taken in this research can be seen in Figure 3.1.

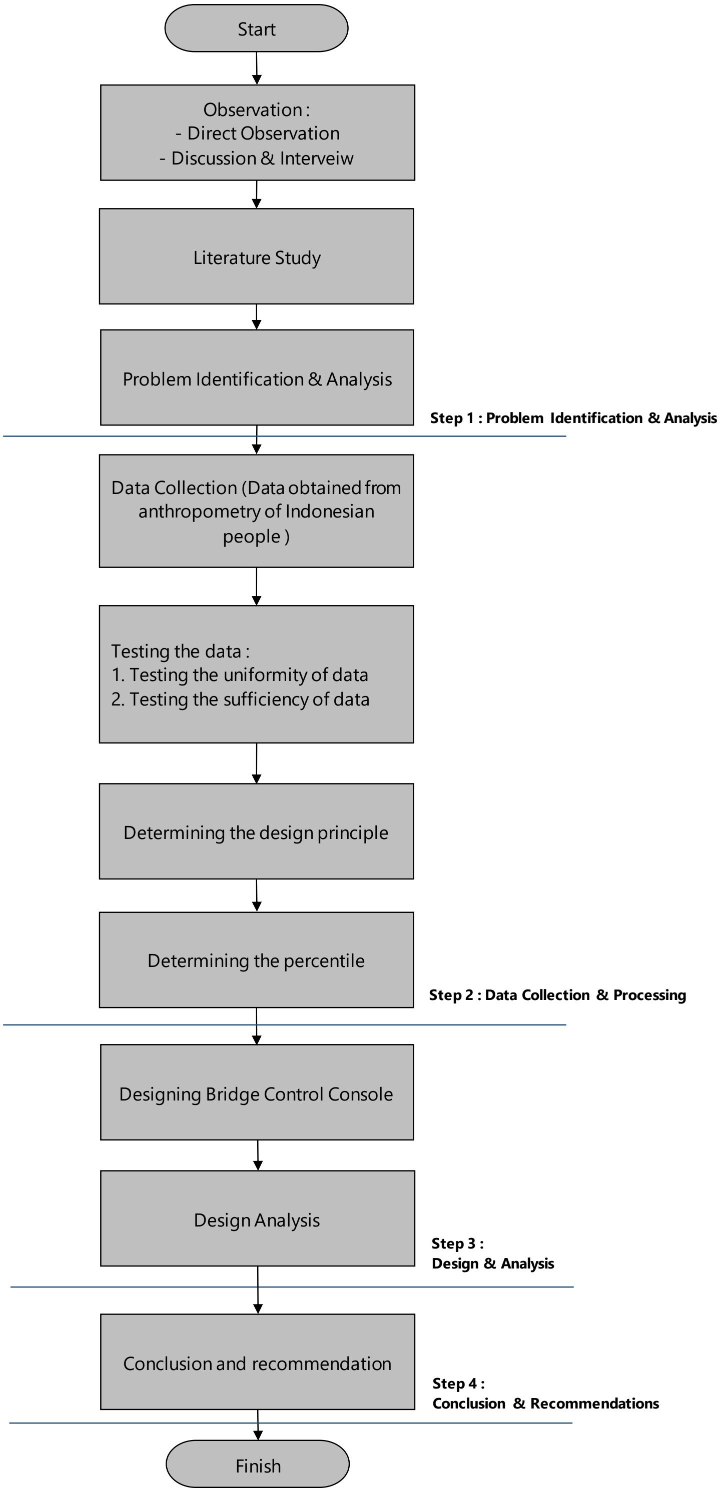

Figure 3.1 Flowchart of Methodology

3.1 Problem Identifications & Analysis

At this stage, the identification and analysis of the problems that occur in the shipping world related to Bridge Control Console design analysis come from the perspective of ergonomics. To strengthen the problem identification of the background and analysis, this stage is divided into several sub-steps as follows :

3.1.1 Observation

In this research, the direct observation is PT. X as a company engaged in shipbuilding business, in which it is during PT. Y as one of the leading manufacturers in electrical equipment for Indonesia's shipping industry. In addition, PT. Y also produces Bridge Control Console (BCC) which becomes the focus (object) in this research. Observation in this research was done through two ways: direct observation and discussion (interview). Direct observation was done to see directly about the observed object and identify the problems that occur or identify the opportunities for the improvement that can be done. Discussions / interviews were conducted to get more information about the issues, obstacles faced by operators related to observation object that is Bridge Control Console.

3.1.2 Literature study

At this stage, a literature source search can be used as a reference for designing an ergonomic Bridge Control Console. The source of literature in this study are (1) Ergonomic definitions including ergonomic parameters, the purpose of ergonomics, and the benefits of applying ergonomics in a design. (2) Anthropometric definitions including anthropometric types, factors affecting anthropometric variability, and the percentile determined. (3) Engineering system design process, approach to design work station, and Bridge Control Console arrangement. (4) The definition of landing ship tank.

All literature review is used as a basis or reference in research from the existing scientific side. Then, the source of this literature will be combined with the results of the observations that had been done so that, the point of view formed in this research can be more comprehensive from the point of view of the literature or actual layout (field practice).

3.2 Data Collecting & Processing

Based on the observations either through direct observation or interview and combined with the literature study conducted, in this stage, the problem identification & analysis is performed. This stage was done with the aim to identify and analyse the problems that occur so that, the next stage can run smoothly and in accordance with the target.

3.2.1 Data collecting

The data used in this study is secondary data obtained from the Indonesian Ergonomics Association and PT.X.The data obtained is Indonesian Anthropometric Data Recap with details as follows:

Table 3.1 Anthropometry Dimension

No.	**Dimension**	**Description**	**No.**	**Dimension**	**Description**	**No.**	**Dimension**	**Description**
1	D1	The height of body	**13**	D13	The length of knee	**25**	D25	The length of shoulder-grip hand forward
2	D2	The height of eye	**14**	D14	The length of popliteal	**26**	D26	The length of head
3	D3	The height of shoulder	**15**	D15	The height of knee	**27**	D27	The width of head
4	D4	The height of elbow	**16**	D16	The height of popliteal	**28**	D28	The length of hand
5	D5	The height of hip	**17**	D17	The width of the shoulder	**29**	D29	The width of hand
6	D6	The height of metacarpals	**18**	D18	The width of upper shoulder	**30**	D30	The length of feet
7	D7	The height of fingertip	**19**	D19	The width of hip	**31**	D31	The width of feet
8	D8	The height of body in sitting position	**20**	D20	The thick of chest	**32**	D32	The length of the arm stretch to the side

No.	Dimension	Description	No.	Dimension	Description	No.	Dimension	Description
9	D9	The height of eye in sitting position	**21**	D21	The thick of stomach	**33**	D33	The length of elbow stretch
10	D10	The height of shoulder in sitting position	**22**	D22	The length of upper arm	**34**	D34	The height of hand grip up in a standing position
11	D11	The height of elbow in sitting position	**23**	D23	The length of forearm	**35**	D35	The height of hand grip up in a sitting position
12	D12	The thickness of thigh	**24**	D24	The length of the range of hands forward	**36**	D36	The length of hand grip forward

3.2.2 Data processing

While the data obtained from PT.X is a standard equipment list data of Bridge Control Console (BCC). The next step in this research is data processing. Data processing was done to obtain the required information at a later stage. The stages of data processing done in this research was data uniformity test, data adequacy test, determining the design principles and determining the anthropometric percentiles specified in the design of the Bridge Control Console.

3.2.2.1 Data uniformity test

Data uniformity test is performed to ensure the data collected comes from the same system and ensures that all data is within the upper control limit range and lower control limits (no outlier data).

3.2.2.2 Data adequacy test

Data adequacy test is used to determine whether the data taken is sufficient or not.

3.2.2.3 Determination of design principles

At this stage, the design principles determination is made.There are several principles of design such as designed for extreme individuals, design for adjustable range, and design for the average. Design for extreme individuals is a design created to meet two principal objectives, namely (1) according to the extreme size (largest or smallest) of the body, and (2) The draft made can still be used comfortably for the size of the majority of the population. The determination of the minimum dimension of a design is based on the value of upper percentile, for example, setting the height/width of the emergency exit. The maximum dimension of a work facility designed is determined based on a lower percentile value, such as the determination of the range of the control facility operated by an operator.The Design for an adjustable range is a design whose size can be changed so that the design is flexible to be used by everyone who has the shape and dimensions of different anthropometric body sizes.

3.2.2.4 Determination of anthropometric percentiles

At this stage, the percentile value determination is applied in the design in accordance with the design principles to be used. The percentile value is determined for each of the anthropometric dimensions of the body that affect the ergonomic Bridge Control Console design dimension.

3.3 Design & Analysis Result

This stage is the design stage of the Bridge Control Console by considering the data that had been collected and the results obtained from the data processing stage. After the design of the bridge control console is completed, it will proceed with the analysis of the results of the design made by adjusting, fitting, and reconciling the design made by the guidance exists.

3.4 Conclusions & Recommendations

The final stage of this research is the conclusion based on the results that was obtained in the previous step to answer the purpose of this research. After that, the stage of preparation of recommendations is done aiming other researchers who conduct research in the same field and recommendations for the observation object those are PT. X and PT. Y in designing Bridge Control Console which is more ergonomic in order to be used savely and comfortably by the operator.

CHAPTER IV
DATA ANALYSIS

In this chapter, the stage of data collection used as an input in this research. After that, the data processing phase is proceed according to the stages that have been described in the research methodology chapter.

4.1 Collecting The Data

The data collected in this research is anthropometry data of Indonesian people from various tribes, male sex with the age range of 21 - 47 years old. The data collected are secondary data obtained from Indonesian Anthropometry Organization. Table 4.1 shows 76 anthropometric data of the Indonesian body according to the criteria mentioned above.

Table 4.1 Anthropometry Data

Dimension	1	2	3	4	etc	73	74	75	76	N
D1	166	177	173.5	167.7	....	172	169.8	164	165.5	76
D2	156.5	164	160	156.2	....	160	158.1	150	154	76
D3	139.5	146	144	139.3	....	144	146.2	132	139.5	76
D4	101	111	108	101	....	110	109.8	102	104.5	76
D5	97	102	92	99.9	....	97	95.6	82	99.5	76
D6	65	89	91	83	....	76	72.3	70	72	76
D7	58.5	61	64	54	....	67	62	56	59	76
D8	85	92	87	89	....	92.5	88.6	90	94	76
D9	75	79	78	78	....	83	77.6	74	83	76
D10	58	62	60	61.5	....	63	58.2	62	68	76
D11	21.5	25	20.4	28.8	....	20	21.5	19	30.5	76
D12	9.6	13	13	11.2	....	16	13.1	12	16	76
D13	54.7	55	65.3	63	....	58	53	52	53	76
D14	49.8	41	33	46	....	44	39.8	40	42	76
D15	52.6	56	54	51.3	....	51	57	49	53	76
D16	42	48	42	39	....	40	42	42	41.5	76
D17	36.1	42	40.6	42	....	52	45.1	40	45	76
D18	35.6	32	34	35.6	....	43	42	38	40.5	76
D19	26.7	35	28	33.5	....	34	31.8	32	38	76

Dimension	1	2	3	4	etc	73	74	75	76	N
D20	12.8	20	17	17.4	....	22	15.8	17	20	76
D21	14.2	15	17	16.3	....	27	21.3	20	19.6	76
D22	35.9	41	34	37.2	....	31	33.2	48	34.5	76
D23	43	50	47	40.5	....	46	47.3	42	44.5	76
D24	76	73.5	73.6	76	....	75	76.2	75	71	76
D25	57.4	60	64	67.8	....	63	26	56	67	76
D26	16.6	17.5	17.1	17.9	....	17	18.7	17	19.4	76
D27	15	18	15.5	14.5	....	16.8	15.6	16	14	76
D28	18	19	18	18.2	....	18.5	19.1	16.5	18.5	76
D29	9.1	9	8.5	8.9	....	8	8.5	7.9	10	76
D30	24.5	27	25	23.7	....	24.5	25.9	23.5	25	76
D31	9.5	10	9	10.3	....	11	7.2	8.5	10	76
D32	171	184	171	175	....	175.5	174	165	168	76
D33	89	93	92	84.6	....	90	93	86	91	76
D34	198	213	201	180.3	....	200	218	189	208	76
D35	120	123	120	129.6	....	130	138	115	126	76
D36	69	70	66	71	....	66	74.2	63	69	76

A total of 76 data collected in this study can be said that the data has met the criteria of the central limit theorem which states that for the amount of the sample is 30 or more will have the properties of the normal distribution.Many natural phenomena that occurred follow the characteristics of normal distribution, therefore the data used in this study meets the criteria in which the amount of the data taken is as many as 76 data (> 30 data).

The anthropometric data above will pass through several tests to ensure that the collected data can be input into the design of the Bridge Control Console to obtain an ergonomic Bridge Control Console design that is convenient to be used by the ship operator.

4.2 Data Processing

At this stage, data that have been collected will be proceed through data uniformity test and data adequacy test. Figure 4.1 is a flowchart of data processing that explains what steps were done in data processing.

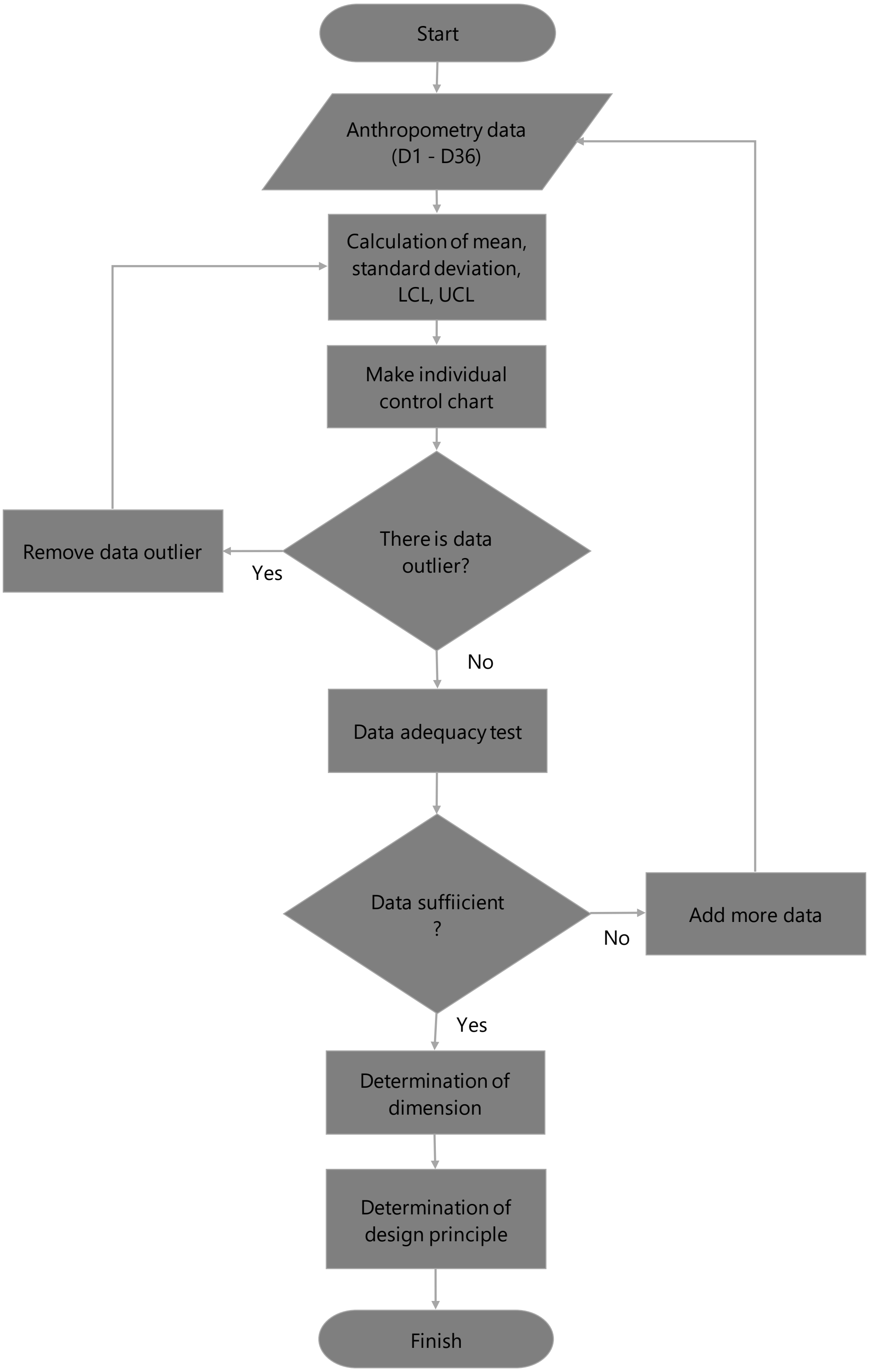

Figure 4.1 Data Processing Flowchart

4.2.1 Data uniformity test

Data uniformity test is conducted in order to know whether the anthropometric data is collected uniformly (some are outside the control limits) or not.

Here is an example of a Uniform Data Test calculation for Dimension D1 (height of body dimension):

a. The calculation of the mean of the height of body (D1) of the collected sample data was performed by using equation 2.2 as described in the previous chapter.

$$\overline{X} = \frac{\sum_{i=1}^{N} X_i}{N}$$

Where,

$\overline{X}$ = the average
X_i = the value of the data to-i
N = the amount of the data

$$\overline{X} = \frac{166 + 177 + 173.5 + 167.7 + \cdots + 172 + 169.8 + 164 + 165.5}{76}$$
$$\overline{X} = \frac{12818.8}{76}$$
$$\overline{X} = 168.67\ cm$$

b. The calculation of the standard deviation of height (D1) was done by using equation 2.3 which had been described in the previous chapter.

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(X_i - \overline{X})^2}{N-1}}$$

Where,
σ = the standard deviation sample
X_i = the value of the data to-i
$\overline{X}$ = the average
N = the number of samples

$$\sigma = \sqrt{\frac{(166-168.67)^2 + (177-168.67)^2 + \cdots + (164-168.67)^2 + (166-168.67)^2}{76-1}}$$

$$\sigma = \sqrt{\frac{7.13 + 69.39 + \cdots + 21.81 + 10.05}{76-1}}$$

$$\sigma = \sqrt{\frac{2157.58}{75}}$$

$$\sigma = \sqrt{28.77}$$

$$\sigma = 5.36\ cm$$

c. The Determination of Lower Control Limit (LCL) and Upper Control Limit (UCL) of the height of body (D1) which was done by using equation 2.4 and 2.5 which had been described in the previous chapter.

$$LCL = \bar{X} - 3\sigma$$

$$LCL = 168.67 - 3\ x\ 5.36$$

$$\boldsymbol{LCL = 152.59\ cm}$$

and

$$\boldsymbol{UCL = \bar{X} + 3\sigma}$$

$$\boldsymbol{UCL = 168.67 + 3\ x\ 5.36}$$

$$\boldsymbol{UCL = 184.75\ cm}$$

Furthermore, the mean, standard deviation, lower control limit, and upper control limit for the dimensions of D2 - D36 were calculated using the same formula as the D1 dimension uniformity test. Table 4.2 shows the recap calculation of the data uniform test value parameters for the dimensions of D1 - D36 :

Table 4.2 Data Uniformity Test Parameter Data Recap of 1st Iteration

Dimension	1	2	3	4	etc	73	74	75	76	Amount of Data (N)	Avg	Stdev	LCL	UCL
D1	166	177	173.5	167.7	....	172	169.8	164	165.5	76	168.67	5.36	152.59	184.75
D2	156.5	164	160	156.2	....	160	158.1	150	154	76	156.78	5.64	139.86	173.7
D3	139.5	146	144	139.3	....	144	146.2	132	139.5	76	140.87	5.34	124.85	156.89
D4	101	111	108	101	....	110	109.8	102	104.5	76	105.11	4.93	90.32	119.9
D5	97	102	92	99.9	....	97	95.6	82	99.5	76	96.52	4.94	81.7	111.34
D6	65	89	91	83	....	76	72.3	70	72	76	74.8	7.98	50.86	98.74
D7	58.5	61	64	54	....	67	62	56	59	76	60.48	5.83	42.99	77.97
D8	85	92	87	89	....	92.5	88.6	90	94	76	88.9	3.79	77.53	100.27
D9	75	79	78	78	....	83	77.6	74	83	76	78.28	4.09	66.01	90.55
D10	58	62	60	61.5	....	63	58.2	62	68	76	60.65	4.25	47.9	73.4
D11	21.5	25	20.4	28.8	....	20	21.5	19	30.5	76	22.56	3.29	12.69	32.43
D12	9.6	13	13	11.2	....	16	13.1	12	16	76	14.37	2.79	6	22.74
D13	54.7	55	65.3	63	....	58	53	52	53	76	57.17	3.57	46.46	67.88
D14	49.8	41	33	46	....	44	39.8	40	42	76	46.33	4.64	32.41	60.25
D15	52.6	56	54	51.3	....	51	57	49	53	76	51.89	2.52	44.33	59.45
D16	42	48	42	39	....	40	42	42	41.5	76	41.65	2.33	34.66	48.64
D17	36.1	42	40.6	42	....	52	45.1	40	45	76	42.32	2.92	33.56	51.08
D18	35.6	32	34	35.6	....	43	42	38	40.5	76	36.91	4.32	23.95	49.87
D19	26.7	35	28	33.5	....	34	31.8	32	38	76	33.13	4.51	19.6	46.66
D20	12.8	20	17	17.4	....	22	15.8	17	20	76	18.02	2.09	11.75	24.29

Dimension	1	2	3	4	etc	73	74	75	76	Amount of Data (N)	Avg	Stdev	LCL	UCL
D21	14.2	15	17	16.3	....	27	21.3	20	19.6	76	18.68	2.95	9.83	27.53
D22	35.9	41	34	37.2	....	31	33.2	48	34.5	76	36.2	4.73	22.01	50.39
D23	43	50	47	40.5	....	46	47.3	42	44.5	76	43.53	4.61	29.7	57.36
D24	76	73.5	73.6	76	....	75	76.2	75	71	76	75.54	3.74	64.32	86.76
D25	57.4	60	64	67.8	....	63	26	56	67	76	64.94	7.15	43.49	86.39
D26	16.6	17.5	17.1	17.9	....	17	18.7	17	19.4	76	18.11	1.28	14.27	21.95
D27	15	18	15.5	14.5	....	16.8	15.6	16	14	76	15.78	1.28	11.94	19.62
D28	18	19	18	18.2	....	18.5	19.1	16.5	18.5	76	18.71	1.31	14.78	22.64
D29	9.1	9	8.5	8.9	....	8	8.5	7.9	10	76	8.68	0.81	6.25	11.11
D30	24.5	27	25	23.7	....	24.5	25.9	23.5	25	76	24.98	1.28	21.14	28.82
D31	9.5	10	9	10.3	....	11	7.2	8.5	10	76	9.57	0.78	7.23	11.91
D32	171	184	171	175	....	175.5	174	165	168	76	172.16	7.53	149.57	194.75
D33	89	93	92	84.6	....	90	93	86	91	76	89.46	4.06	77.28	101.64
D34	198	213	201	180.3	....	200	218	189	208	76	203.66	8.99	176.69	230.63
D35	120	123	120	129.6	....	130	138	115	126	76	124.51	9.97	94.6	154.42
D36	69	70	66	71	....	66	74.2	63	69	76	71.14	5.39	54.97	87.31

After the average parameters, the standard deviation, lower control limit (LCL), and upper control limit (UCL) were obtained, then all of these parameters and the values of all the data samples were input into the control chart graph to see whether there is any data which is beyond the control limit or not. The data uniformity test in this research was done by using Software Minitab 16 in the following way:

1. Open the worksheet in which there is data dimension to be tested
2. Choose Start → Control Charts → Variables Charts for Individuals → Individuals
3. In Variables, enter "Data Samples" to be tested
4. Click OK in each dialog box

Here is the result of the data uniformity test of the height of body in the 1st Iteration

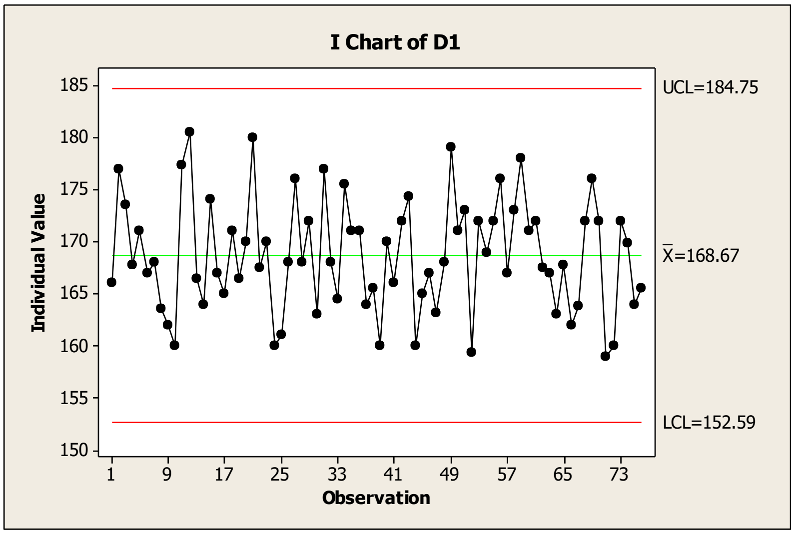

Figure 4.2 Data Uniformity Test of 1st Iteration for The Dimension D1

Conclusion :

The individual charts of the data uniformity test of the 1st iteration for the dimension of D1 shows that the height of the body (D1) used in this research is uniform. Therefore, the data uniformity test for D1 is sufficient for the 1st iteration and no additional iterations are necessary.

The data uniformity test for the dimension of D2 - D36 was performed by using the same method as the data uniformity test conducted for D1 dimension. Here is the result of D1 - D36 data uniformity test using Minitab 16 software.

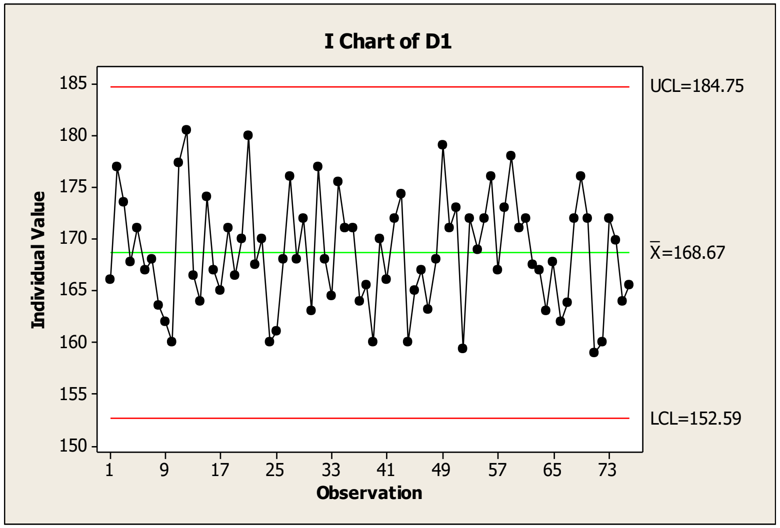

Figure 4.3 The Data Uniformity Test of the 1st Iteration for The Dimension of D1.

Conclusion : The Data from the Dimension of D1 is uniform, the iteration is stopped.

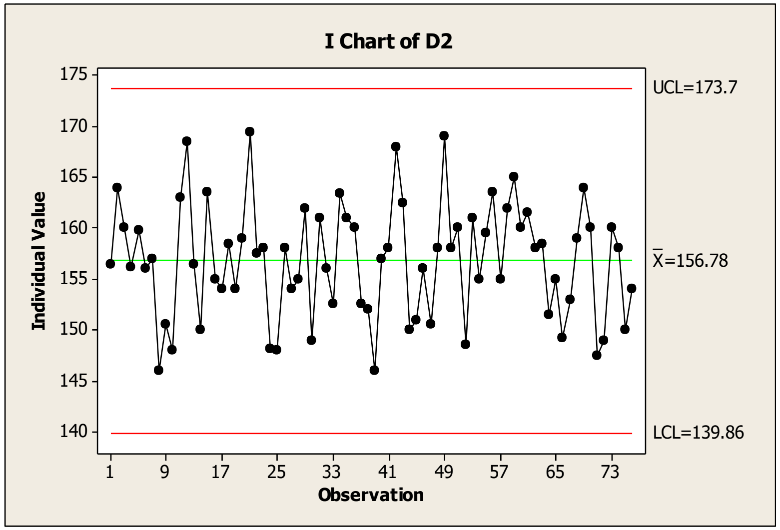

Figure 4.4 The Data Uniformity Test of the 1st Iteration for The Dimension of D2.

Conclusion : The data from the Dimension of D2 is uniform, the iteration is stopped.

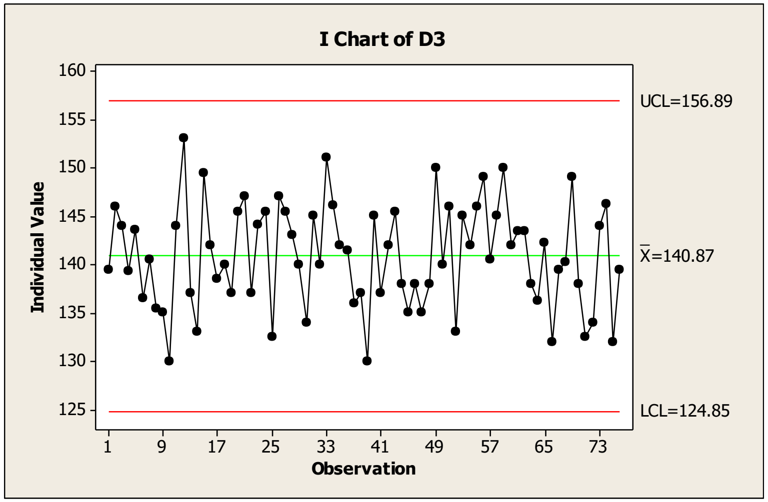

Figure 4.5 The Data Uniformity Test of the 1st Iteration for The Dimension of D3.

Conclusion : The data from the Dimension of D3 is uniform, the iteration is stopped.

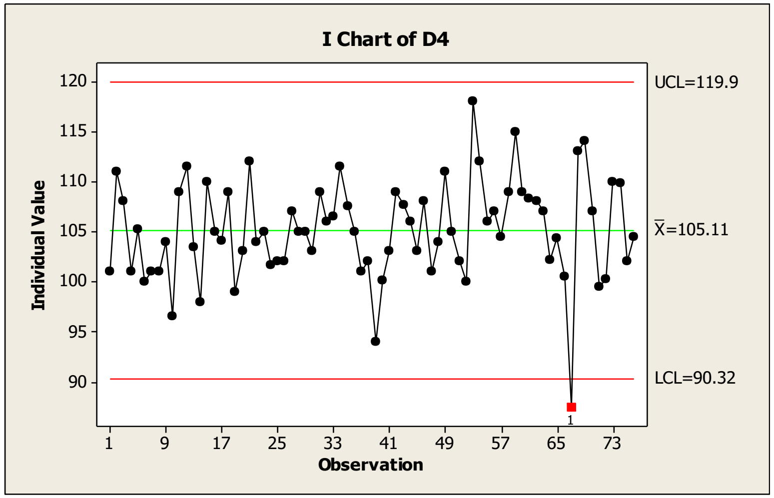

Figure 4.6 The Data Uniformity Test of the 1st Iteration for The Dimension of D4.

Conclusion : The 67th data is out of control (more than 3 times of the standard deviation of the center line). The data uniformity test was continued to the iteration 2 by releasing the 67th data

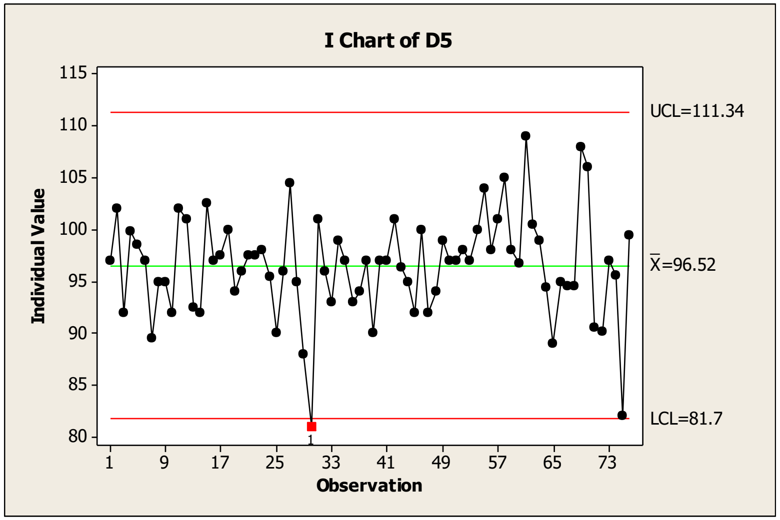

Figure 4.7 The Data Uniformity Test of the 1st Iteration for The Dimension of D5.

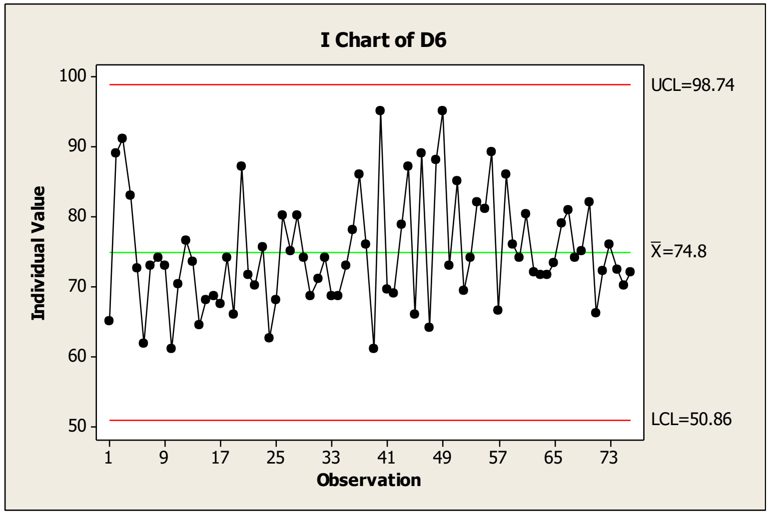

Figure 4.8 The Data Uniformity Test of the 1st Iteration for The Dimension of D6.

Conclusion : The 30th data is out of control (more than 3 times of the standard deviation of the center line). The data uniformity test was continued to the 2nd iteration by releasing the 30th data

Conclusion : The data from the Dimension of D3 is uniform, the iteration is stopped.

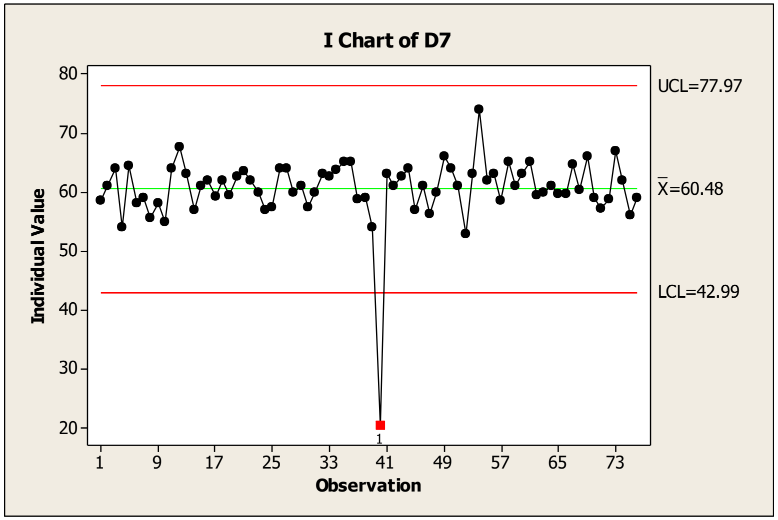

Figure 4.9 The Data Uniformity Test of the 1st Iteration for The Dimension of D7.

Conclusion : The 40th data is out of control (more than 3 times of the standard deviation of the center line). The data uniformity test was continued to the 2nd iteration by releasing the 40th data.

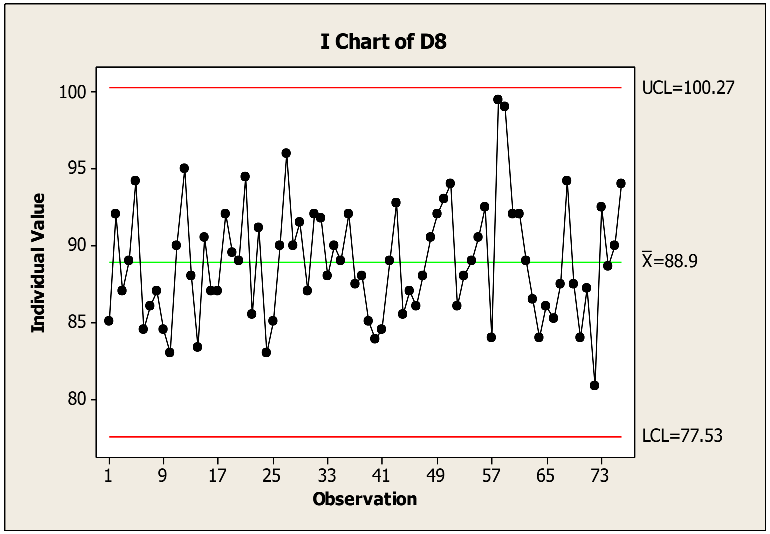

Figure 4.10 The Data Uniformity Test of the 1st Iteration for The Dimension of D8.

Conclusion : The data from the dimension of D8 is uniform, the iteration is stopped.

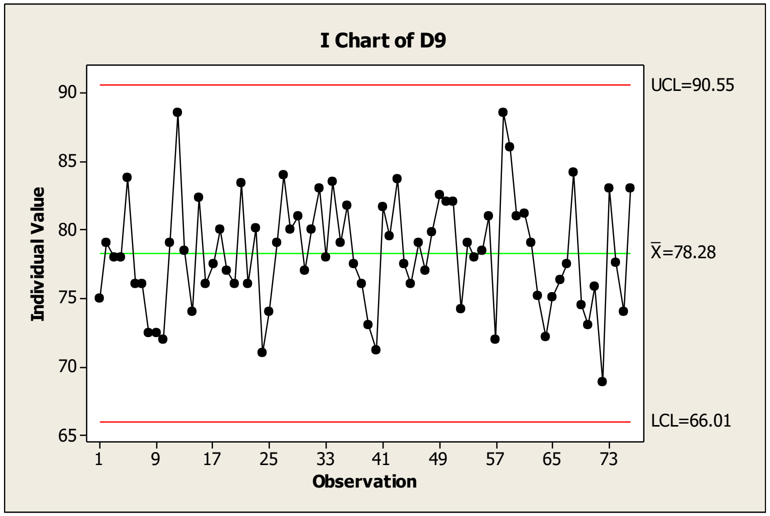

Figure 4.11 The Data Uniformity Test of the 1st Iteration for The Dimension of D9.

Conclusion : The data from the Dimension of D9 is uniform, the iteration is stopped.

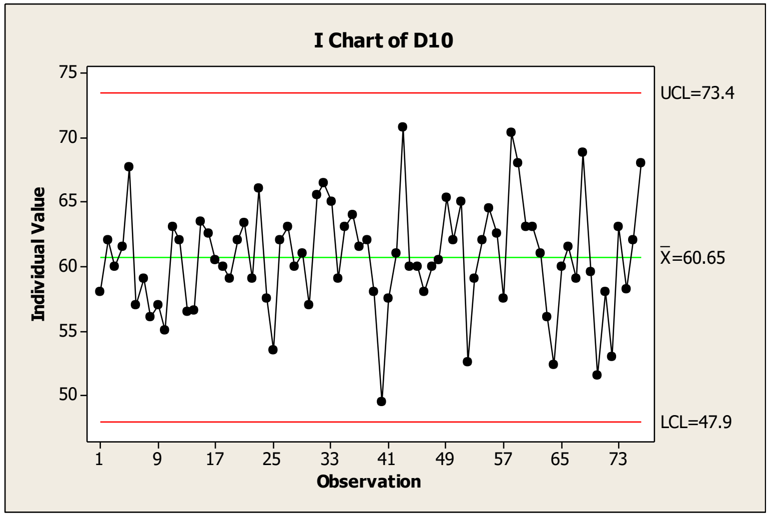

Figure 4.12 The Data Uniformity Test of the 1st Iteration for The Dimension of D10.

Conclusion : The data from the Dimension of D10 is uniform, the iteration is stopped.

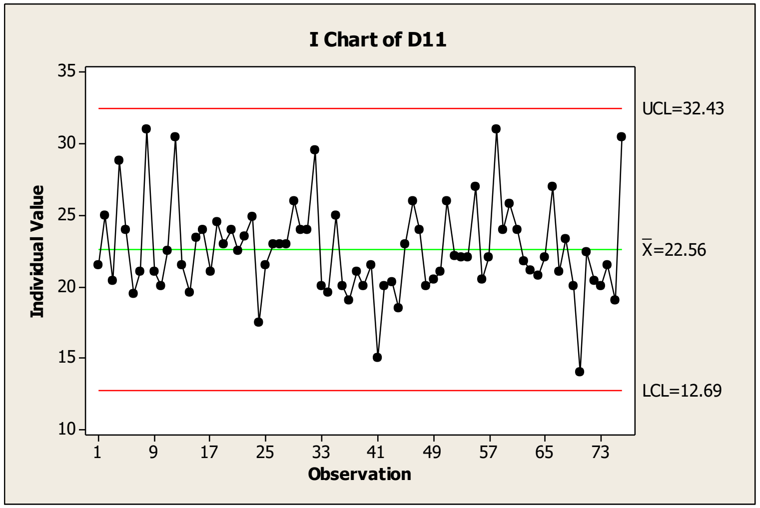

Figure 4.13 The Data Uniformity Test of The 1st Iteration for the Dimension of D11.

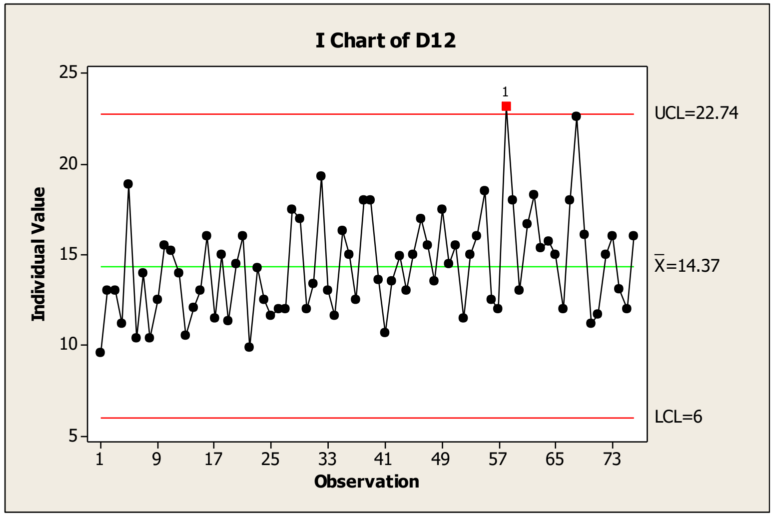

Figure 4.14 The Data Uniformity Test of The 1st Iteration for the Dimension of D12.

Conclusion : The data from the Dimension of D11 is uniform, the iteration is stopped.

Conclusion : The 58th data is out of control (more than 3 times of the standard deviation of the center line). Data uniformity test was continued to the 2nd iteration by releasing the 58th data.

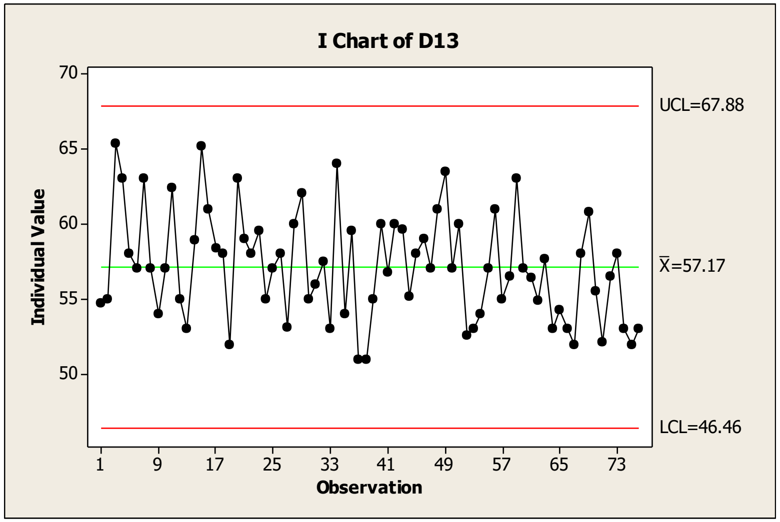

Figure 4.15 The Data Uniformity Test of The 1st Iteration for The Dimension of D13.

Conclusion : The data from the Dimension of D13 is uniform, the iteration is stopped.

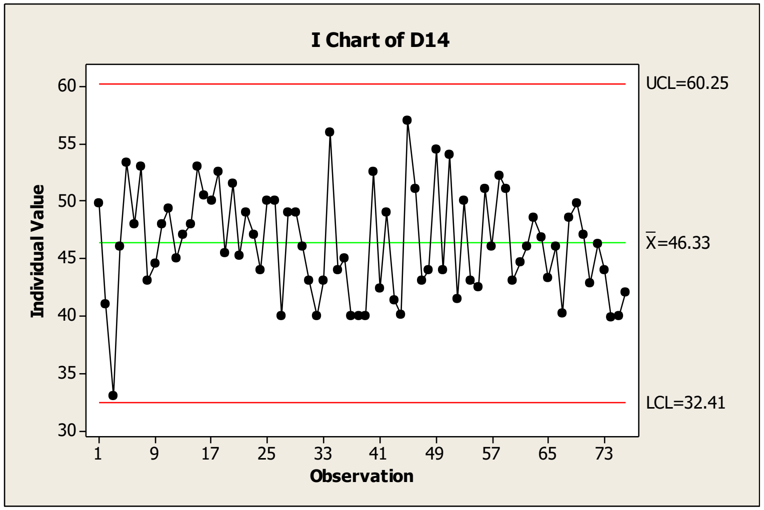

Figure 4.16 The Data Uniformity Test of The 1st Iteration for The Dimension of D14.

Conclusion : The data from the Dimension of D14 is uniform, the iteration is stopped.

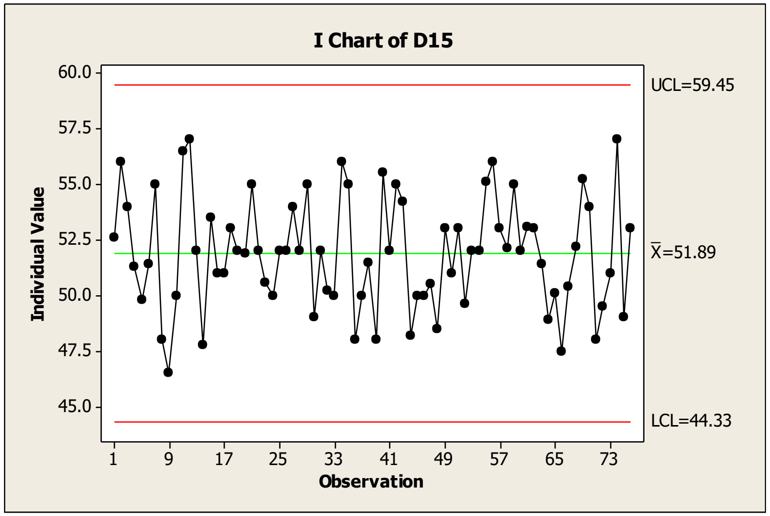

Figure 4.17 The Data Uniformity Test of the 1st Iteration for The Dimension of D15.

Conclusion : The data from the Dimension of D15 is uniform, the iteration is stopped.

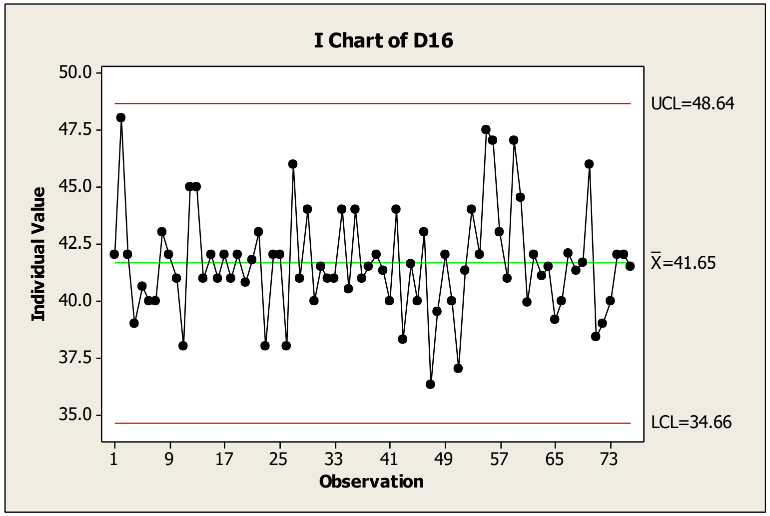

Figure 4.18 The Data Uniformity Test of the 1st Iteration for The Dimension of D16.

Conclusion : The data from the Dimension of D16 is uniform, the iteration is stopped.

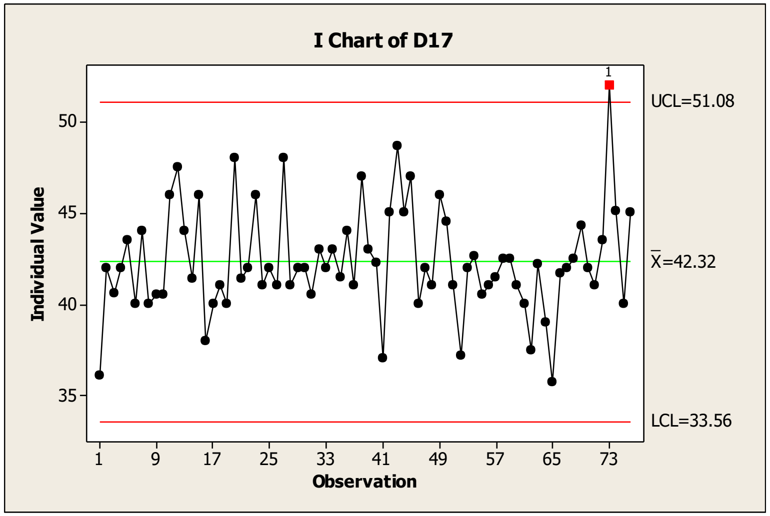

Figure 4.19 The Data Uniformity Test of The 1st Iteration for The Dimension of D17.

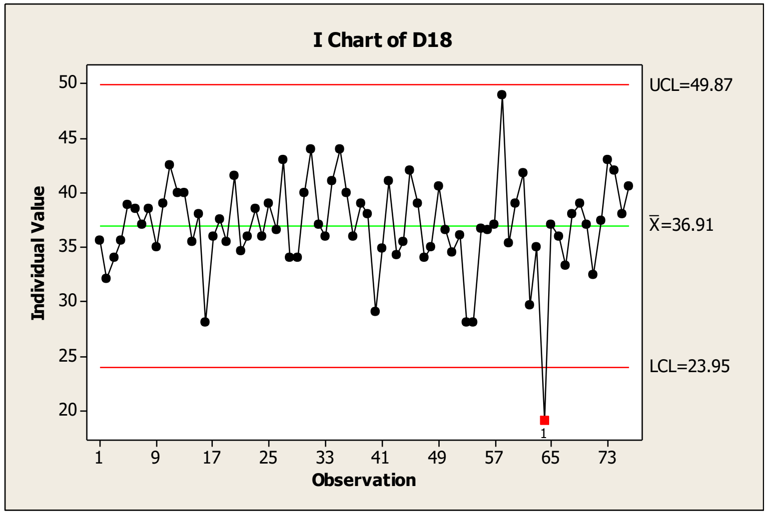

Figure 4.20 The Data Uniformity Test of The 1st Iteration for The Dimension of D18.

Conclusion : The 73rd data is out of control (more than 3 times of the standard deviation of the center line). The data uniformity test was continued to the 2nd iteration by releasing the 73rd data.

Conclusion : The 64th data is out of control (more than 3 times of the standard deviation of the center line). The data uniformity test was continued to the 2nd iteration by releasing the 64th data.

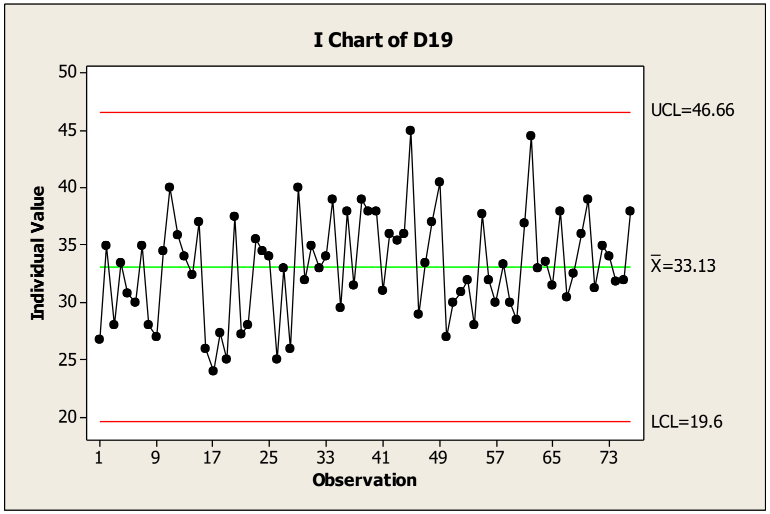

Figure 4.21 The Data Uniformity Test of the 1st Iteration for the Dimension of D19.

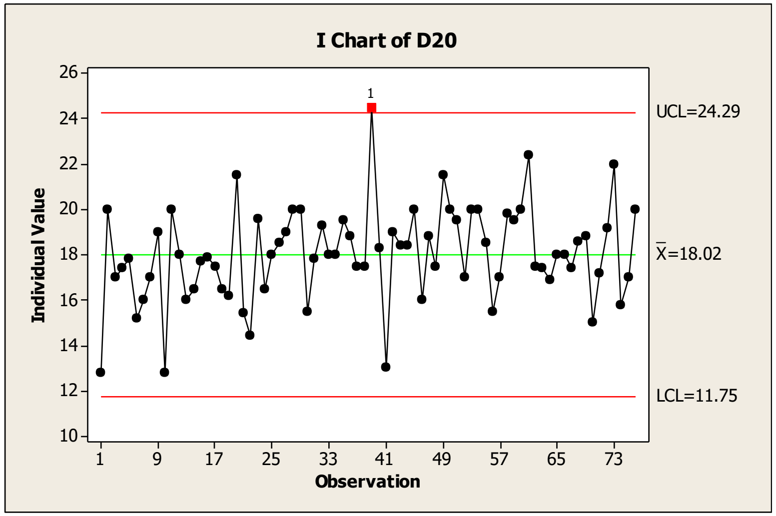

Figure 4.22 The Data Uniformity Test of the 1st iteration for The Dimension of D20.

Conclusion : The Data from the Dimension of D19 is uniform, the iteration is stopped.

Conclusion : The 39th data is out of control (more than 3 times of the standard deviation of the center line). The data uniformity test was continued to the 2nd iteration by releasing the 39th data.

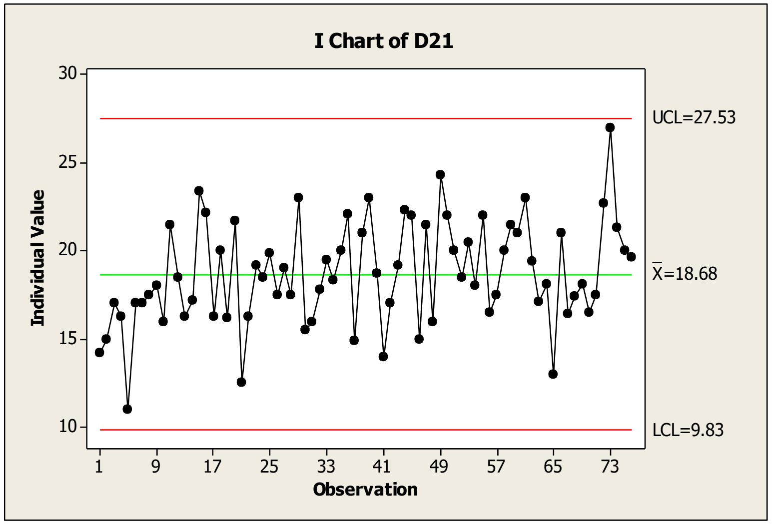

Figure 4.23 The Data Uniformity Test of the 1st iteration for the Dimension of D21.

Conclusion : The Data from the Dimension of D21 is uniform, the iteration is stopped.

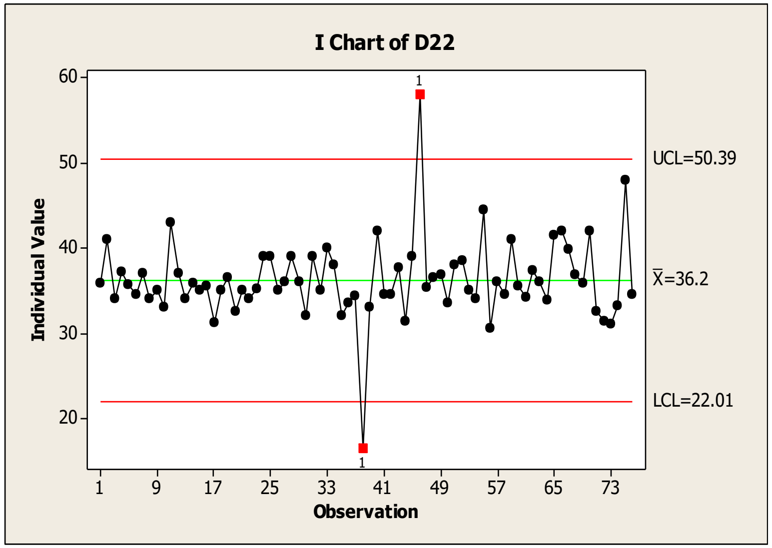

Figure 4.24 The Data Uniformity Test of the 1st iteration for the Dimension of D22,

Conclusion : The 38th and 46th data are out of control (more than 3 times of the standard deviation of the center line).The Data uniformity test was continued to the 2nd iteration by releasing the 38th and 46th data.

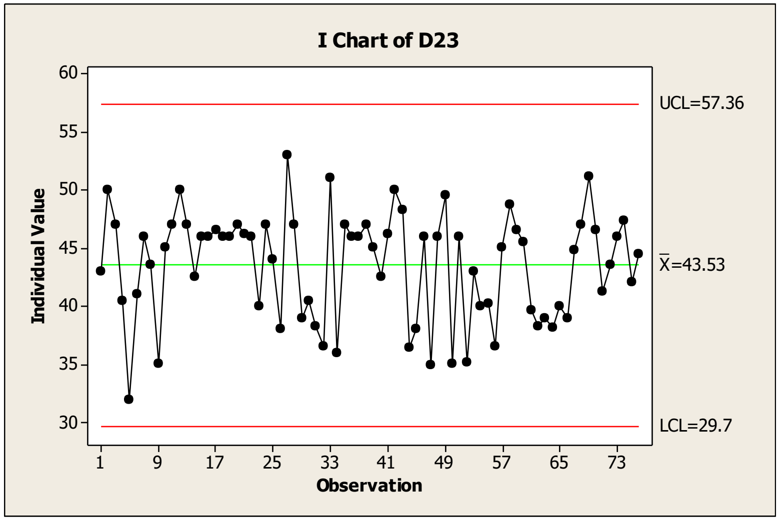

Figure 4.25 The Data Uniformity Test of the 1st iteration for the Dimension of D23.

Conclusion : The Data from the Dimension of D23 is uniform, the iteration is stopped.

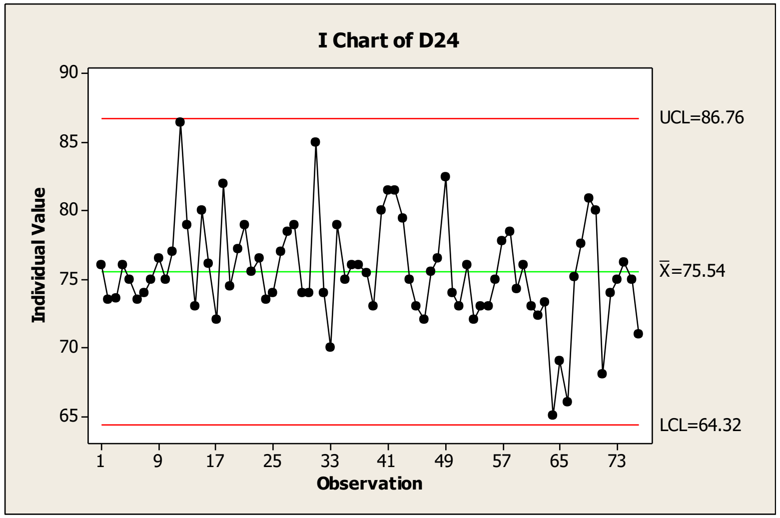

Figure 4.26 The Data Uniformity Test of the 1st iteration for the Dimension of D24.

Conclusion : The Data from the Dimension of D24 is uniform, the iteration is stopped.

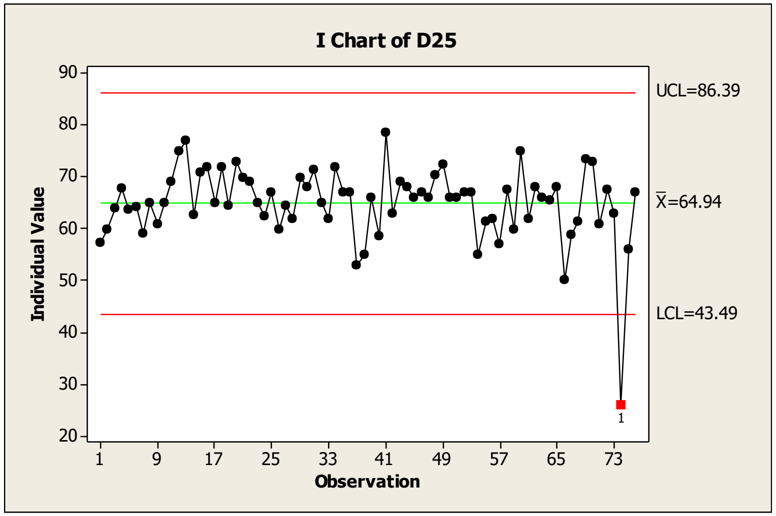

Figure 4.27 The Data Uniformity Test of the 1st iteration for the Dimension of D25.

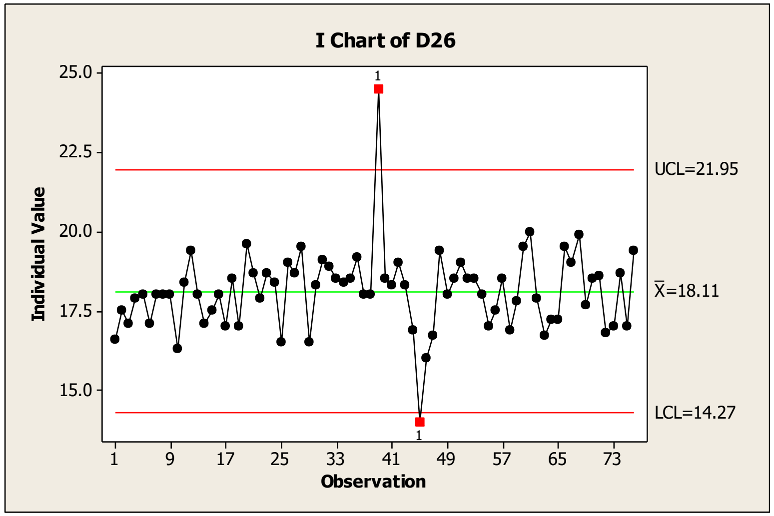

Figure 4.28 The Data Uniformity Test of the 1st iteration for the Dimension of D26.

Conclusion : The 39th data is out of control (more than 3 times of the standard deviation of the center line). The data uniformity test was continued to the 2nd iteration by releasing the 74th data.

Conclusion : The 39th and 45th data are out of control (more than 3 times of the standard deviation of the center line). Data uniformity test was continued to 2nd iteration by releasing the 39th and 45th data.

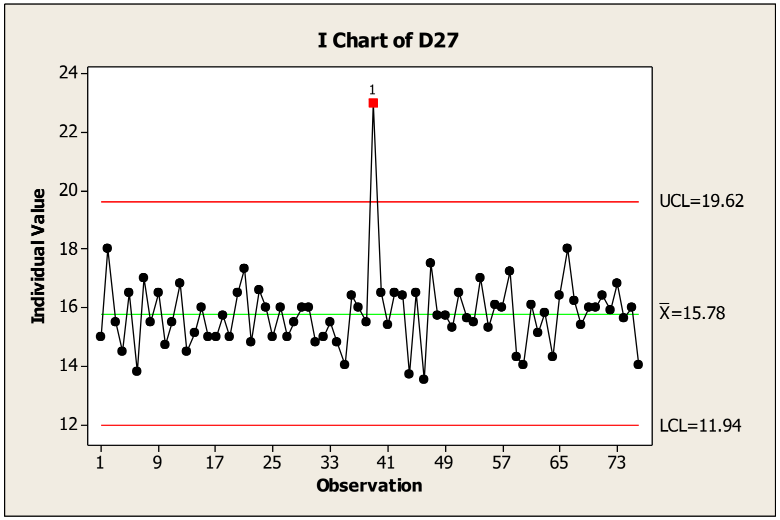

Figure 4.29 The Data Uniformity Test of the 1st iteration for Dimension of D27.

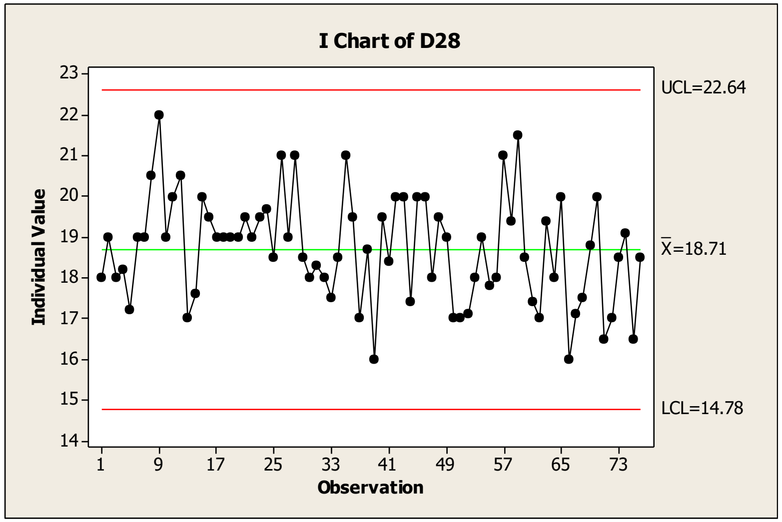

Figure 4.30 The Data Uniformity Test of the 1st iteration for the Dimension of D28.

Conclusion : The 39th data is out of control (more than 3 times of the standard deviation of the center line). The data uniformity test was continued to the 2nd iteration by releasing the 39th data.

Conclusion : The data from the Dimension of D28 is uniform, the iteration is stopped

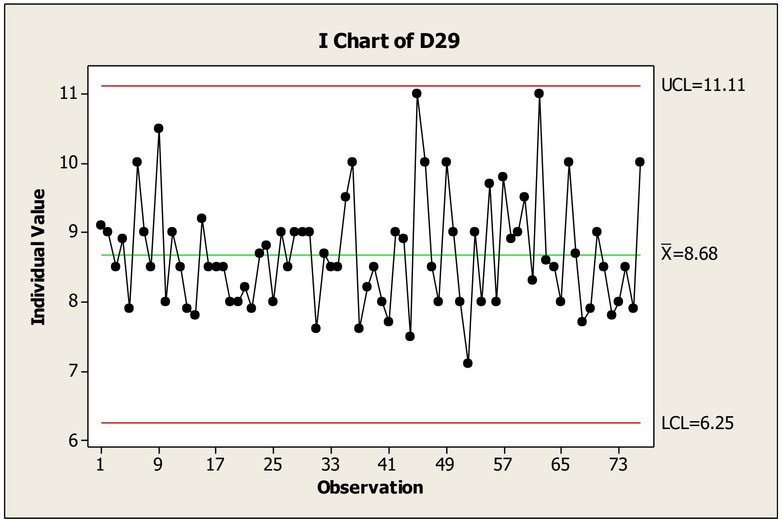

Figure 4.31 The Data Uniformity Test of the 1st iteration for the Dimension of D29.

Conclusion : The Data from the Dimension of D29 is uniform, the iteration is stopped.

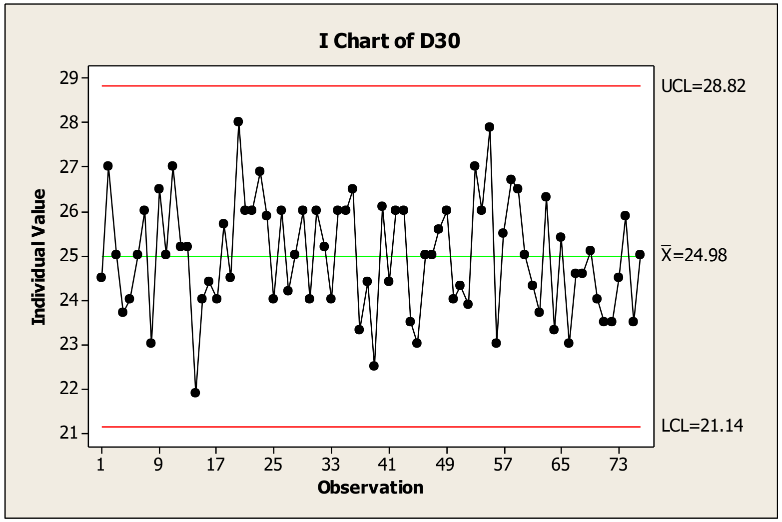

Figure 4.32 The Data Uniformity Test of the 1st iteration for the Dimension of D30.

Conclusion : The data from the Dimension of D30 is uniform, the iteration is stopped.

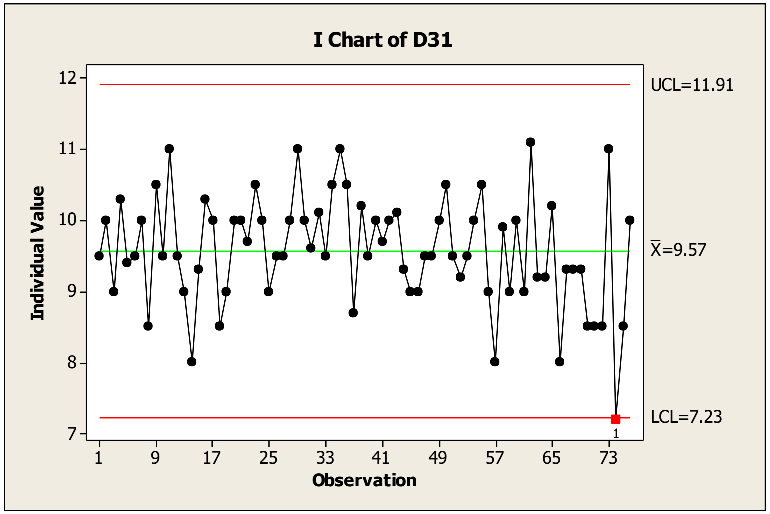

Figure 4.33 The Data Uniformity Test of the 1st iteration for the Dimension of D31.

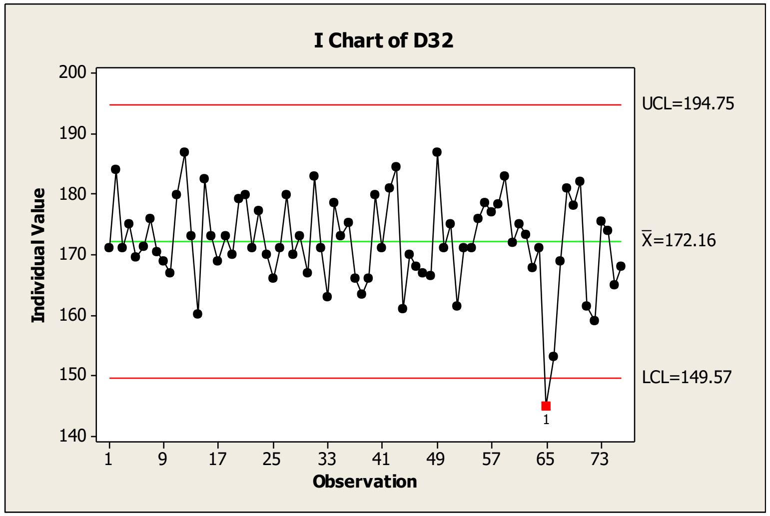

Figure 4.34 The Data Uniformity Test of the 1st iteration for the Dimension of D32.

Conclusion : The 74th data is out of control (more than 3 times of the standard deviation of the center line).The Data uniformity test was continued to the 2nd iteration by releasing the 74th data.

Conclusion : The 65th data is out of control (more than 3 times of the standard deviation of the center line).The data uniformity test was continued to the 2nd iteration by releasing the 65th data.

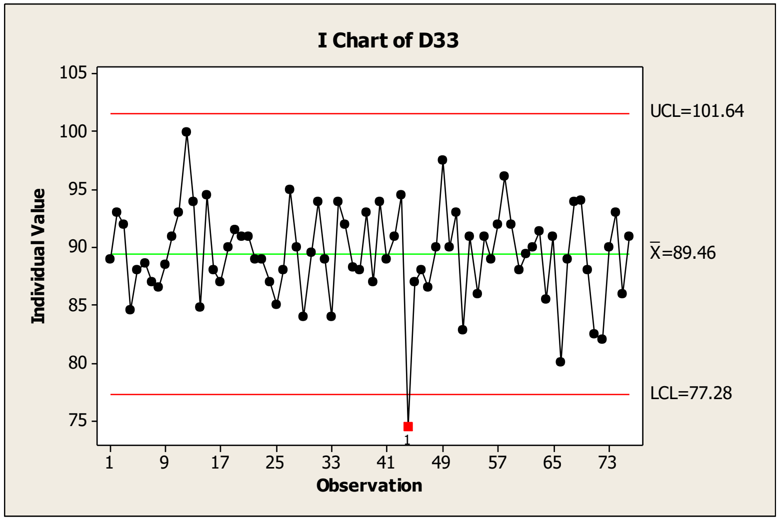

Figure 4.35 The Data Uniformity Test of the 1st iteration for the Dimension of D33.

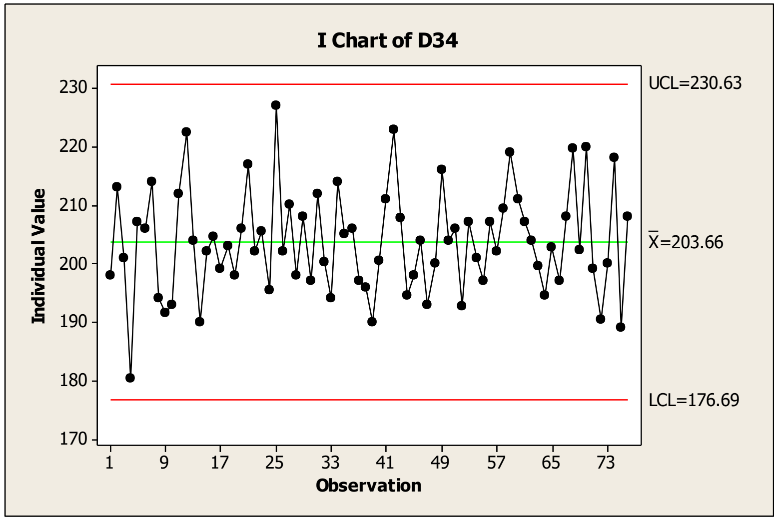

Figure 4.36 The Data Uniformity Test of the 1st iteration for the Dimension of D34.

Conclusion : The 65th data is out of control (more than 3 times of the standard deviation of the center line). Data uniformity test was continued to 2nd iteration by releasing the 44th data.

Conclusion : The Data from the Dimension of D34 is uniform, the iteration is stopped.

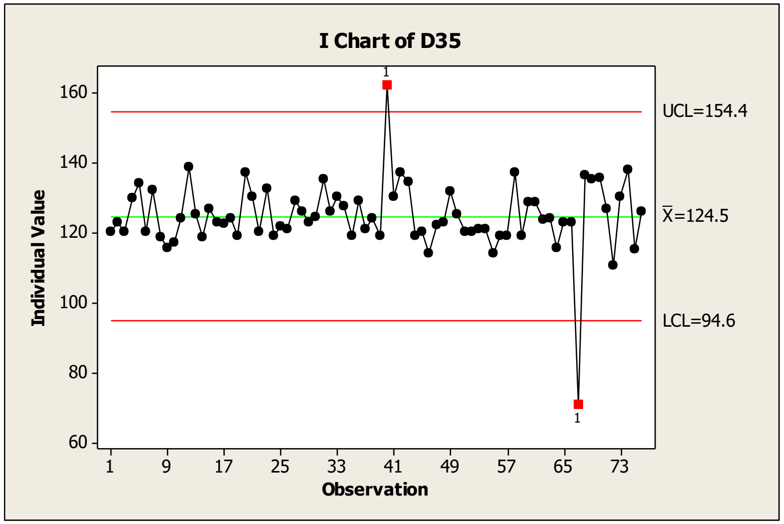

Figure 4.37 The Data Uniformity Test of the 1st iteration for the Dimension of D35

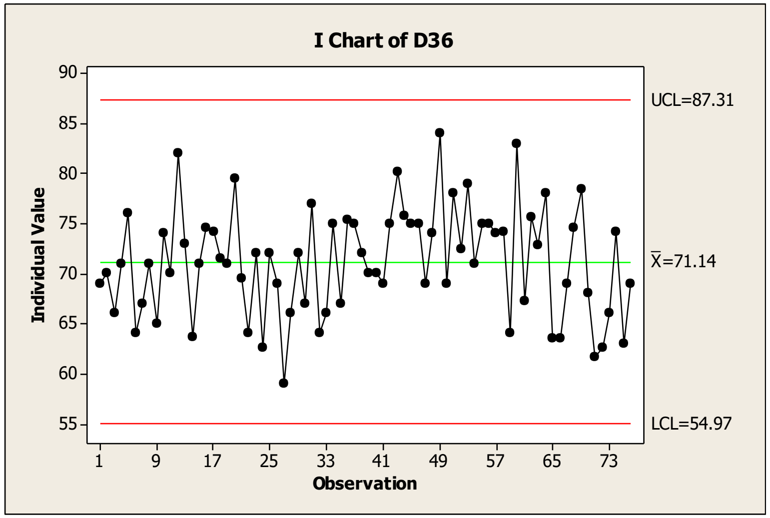

Figure 4.38 The Data Uniformity Test of the 1st iteration for the Dimension of D36.

Conclusion: The 40th and 67th data are out of control (more than 3 times of the standard deviation of the center line). The data uniformity test was continued to the 2nd iteration by releasing the 40th and 67th data.

Conclusion : The data from the Dimension of D36 is uniform, the iteration is stopped.

Here is shown the data test recapitulation result of the 1st iteration of the data uniformity test obtained by the help of Minitab 16 software.

Table 4.3 The Recapitulation of The 1st Iteration of Data Uniformity Test Results

Dimension	**1**	**2**	**3**	**4**	**etc**	**73**	**74**	**75**	**76**	**N**	**Avg**	**Stdev**	**LCL**	**UCL**	**Conclusion**	**Data Outlier**	**Decision**
D1	166	177	173.5	167.7	....	172	169.8	164	165.5	76	168.67	5.36	152.59	184.75	Uniform		Iteration stopped
D2	156.5	164	160	156.2	....	160	158.1	150	154	76	156.78	5.64	139.86	173.7	Uniform		Iteration stopped
D3	139.5	146	144	139.3	....	144	146.2	132	139.5	76	140.87	5.34	124.85	156.89	Uniform		Iteration stopped
D4	101	111	108	101	....	110	109.8	102	104.5	76	105.11	4.93	90.32	119.9		67	**Continued to 2nd iteration**
D5	97	102	92	99.9	....	97	95.6	82	99.5	76	96.52	4.94	81.7	111.34	Not uniform	30	**Continued to the 2nd iteration**
D6	65	89	91	83	....	76	72.3	70	72	76	74.8	7.98	50.86	98.74	Uniform		Iteration stopped
D7	58.5	61	64	54	....	67	62	56	59	76	60.48	5.83	42.99	77.97	Not uniform	40	**Continued to the 2nd iteration**
D8	85	92	87	89	....	92.5	88.6	90	94	76	88.9	3.79	77.53	100.27	Uniform		**Continued to the2nd iteration**
D9	75	79	78	78	....	83	77.6	74	83	76	78.28	4.09	66.01	90.55	Uniform		Iteration stopped
D10	58	62	60	61.5	....	63	58.2	62	68	76	60.65	4.25	47.9	73.4	Uniform		Iteration stopped

Dimension	1	2	3	4	etc	73	74	75	76	N	Avg	Stdev	LCL	UCL	Conclusion	Data Outlier	Decision
D11	21.5	25	20.4	28.8	....	20	21.5	19	30.5	76	22.56	3.29	12.69	32.43	Uniform		Iteration stopped
D12	9.6	13	13	11.2	....	16	13.1	12	16	76	14.37	2.79	6	22.74	Not uniform	58	**Continued to the 2nd iteration**
D13	54.7	55	65.3	63	....	58	53	52	53	76	57.17	3.57	46.46	67.88	Uniform		Iteration stopped
D14	49.8	41	33	46	....	44	39.8	40	42	76	46.33	4.64	32.41	60.25	Uniform		Iteration stopped
D15	52.6	56	54	51.3	....	51	57	49	53	76	51.89	2.52	44.33	59.45	Uniform		Iteration stopped
D16	42	48	42	39	....	40	42	42	41.5	76	41.65	2.33	34.66	48.64	Uniform		Iteration stopped
D17	36.1	42	40.6	42	....	52	45.1	40	45	76	42.32	2.92	33.56	51.08	Not uniform	73	**Continued to the 2nd iteration**
D18	35.6	32	34	35.6	....	43	42	38	40.5	76	36.91	4.32	23.95	49.87	Not uniform	64	**Continued to the 2nd iteration**
D19	26.7	35	28	33.5	....	34	31.8	32	38	76	33.13	4.51	19.6	46.66	Uniform		Iteration stopped
D20	12.8	20	17	17.4	....	22	15.8	17	20	76	18.02	2.09	11.75	24.29	Not uniform	39	**Continued to the 2nd iteration**
D21	14.2	15	17	16.3	....	27	21.3	20	19.6	76	18.68	2.95	9.83	27.53	Uniform		Iteration stopped
D22	35.9	41	34	37.2	....	31	33.2	48	34.5	76	36.2	4.73	22.01	50.39	Not uniform	38, 46	**Continued to the 2nd iteration**
D23	43	50	47	40.5	....	46	47.3	42	44.5	76	43.53	4.61	29.7	57.36	Uniform		Iteration stopped

Dimension	1	2	3	4	etc	73	74	75	76	N	Avg	Stdev	LCL	UCL	Conclusion	Data Outlier	Decision
D24	76	73.5	73.6	76	....	75	76.2	75	71	76	75.54	3.74	64.32	86.76	Uniform		Iteration stopped
D25	57.4	60	64	67.8	....	63	26	56	67	76	64.94	7.15	43.49	86.39	Not uniform	74	**Continued to the 2^{nd} iteration**
D26	16.6	17.5	17.1	17.9	....	17	18.7	17	19.4	76	18.11	1.28	14.27	21.95	Not uniform	39, 45	**Continued to the 2^{nd} iteration**
D27	15	18	15.5	14.5	....	16.8	15.6	16	14	76	15.78	1.28	11.94	19.62	Not uniform	39	**Continued to the 2^{nd} iteration**
D28	18	19	18	18.2	....	18.5	19.1	16.5	18.5	76	18.71	1.31	14.78	22.64	Uniform		Iteration stopped
D29	9.1	9	8.5	8.9	....	8	8.5	7.9	10	76	8.68	0.81	6.25	11.11	Uniform		Iteration stopped
D30	24.5	27	25	23.7	....	24.5	25.9	23.5	25	76	24.98	1.28	21.14	28.82	Uniform		Iteration stopped
D31	9.5	10	9	10.3	....	11	7.2	8.5	10	76	9.57	0.78	7.23	11.91	Not uniform	74	**Continued to the 2^{nd} iteration**
D32	171	184	171	175	....	175.5	174	165	168	76	172.16	7.53	149.57	194.75	Not uniform	65	**Continued to the 2^{nd} iteration**
D33	89	93	92	84.6	....	90	93	86	91	76	89.46	4.06	77.28	101.64	Not uniform	44	**Continued to the 2^{nd} iteration**
D34	198	213	201	180.3	....	200	218	189	208	76	203.66	8.99	176.69	230.63	Uniform		Iteration stopped
D35	120	123	120	129.6	....	130	138	115	126	76	124.51	9.97	94.6	154.42	Not uniform	40, 67	**Continued to the 2^{nd} iteration**

Dimension	1	2	3	4	etc	73	74	75	76	N	Avg	Stdev	LCL	UCL	Conclusion	Data Outlier	Decision
D36	69	70	66	71	....	66	74.2	63	69	76	71.14	5.39	54.97	87.31	Uniform		Iteration stopped

Note :
- Yellow Color : Outlier data indicated
- Other outlier (not included in the table above) is shown in the attachment data.

Based on the result of the data uniformity test of the 1st iteration data for the dimension of D1 – D6, there are several dimensions that are not uniform (there is data outlier) so that the dimension still need to be done in the data uniformity test of the 2nd iteration by releasing the data outlier from each data dimension. Approximately 41.67% (15 of 36) of the total dimensions of Indonesian anthropometry sampled in this study need to be tested by data uniformity test of the 2nd iteration. The process of data uniformity test of the 2nd iteration needs to be done in the same way as the 1st iteration.

The following is an example of the data uniformity test of the 2nd iteration for D25 (The length of shoulder-grip hand forward) :

a. The average calculation of Dimension D25 (The length of shoulder-grip hand forward) of the sample data collected after the data outlier on the 1st iteration was issued.

$$\overline{X} = \frac{\sum_{i=1}^{N} X_i}{N}$$

Where,
$\bar{X}$= the average
X_i = the value of the data to-i
N= the amount of the data

$$\bar{X} = \frac{57.4 + 60 + 64 + 67.8 + \cdots + 67.5 + 63 + 56 + 67}{75}$$
$$\bar{X} = \frac{4909.4}{75}$$
$$\bar{X} = 65.46\ cm$$

b. The calculation of the standard deviation of Dimension D25 (The length of shoulder-grip hand forward) was done by using equation 2.3 as described in the previous chapter.

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(X_i - \bar{X})^2}{N-1}}$$

Where,
σ = the standard deviation sample
X_i= the value of the data to-i
$\bar{X}$ = the average
N = the Number of samples

$$\sigma = \sqrt{\frac{(57.4 - 65.46)^2 + (60 - 65.46)^2 + \cdots + (56 - 65.46)^2 + (67 - 65.46)^2}{75 - 1}}$$
$$\sigma = \sqrt{\frac{64.96 + 29.81 + \cdots + 89.49 + 2.37}{75 - 1}}$$
$$\sigma = \sqrt{\frac{2298.06}{74}}$$
$$\sigma = \sqrt{31.05}$$
$$\sigma = 5.57\ cm$$

c. The determination of Lower Control Limit (LCL) and Upper Control Limit (UCL) of height of the body data (D1) was done by using equation 2.4 and 2.5 which had been described in the previous chapter.

$$LCL = \bar{X} - 3\sigma$$
$$LCL = 65.46 - 3\,x\,5.57$$
$$LCL = 48.75\ cm$$

and

$$UCL = \bar{X} + 3\sigma$$
$$UCL = 65.46 + 3\,x\,5.57$$
$$UCL = 82.17\ cm$$

Furthermore, the averages, standard deviation, lower control limit, and upper control limit for other dimensions were calculated using the same formula as the dimension D25 data uniformity test. Table 4.2 shows the recap calculation of the data uniformity test value parameters for the dimensions of D1 - D36:

Table 4.4 Data Uniformity Test Parameter Data Recap of 2nd Iteration

Dimension	1	2	3	4	etc	72	73	74	75	N	Avg	Stdev	LCL	UCL
D4	101	111	108	101	....	110	109.8	102	104.5	75	105.34	4.52	91.78	118.9
D5	97	102	92	99.9	....	97	95.6	82	99.5	75	96.72	4.63	82.83	110.61
D7	58.5	61	64	54	....	67	62	56	59	75	61.01	3.55	50.36	71.66
D12	9.6	13	13	11.2	....	16	13.1	12	16	75	14.25	2.61	6.42	22.08
D17	36.1	42	40.6	42	....	43.5	45.1	40	45	75	42.19	2.71	34.06	50.32
D18	35.6	32	34	35.6	....	43	42	38	40.5	75	37.15	3.82	25.69	48.61
D20	12.8	20	17	17.4	....	22	15.8	17	20	75	17.93	1.96	12.05	23.81
D22	35.9	41	34	37.2	....	33.2	48	34.5		74	36.17	3.34	26.15	46.19
D25	57.4	60	64	67.8	....	67.5	63	56	67	75	65.46	5.57	48.75	82.17
D26	16.6	17.5	17.1	17.9	....	18.7	17	19.4		74	18.08	0.95	15.23	20.93
D27	15	18	15.5	14.5	....	16.8	15.6	16	14	75	15.69	0.97	12.78	18.6
D31	9.5	10	9	10.3	....	8.5	11	8.5	10	75	9.61	0.73	7.42	11.8
D32	171	184	171	175	....	175.5	174	165	168	75	172.53	6.88	151.89	193.17
D33	89	93	92	84.6	....	90	93	86	91	75	89.66	3.7	78.56	100.76
D35	120	123	120	129.6	....	138	115	126		74	124.72	6.6	104.92	144.52

Same as the process on the 1st iteration, the data uniformity test of the 2nd iteration was done by using Minitab 16 software. Here is the Individual Control Chart graph obtained from Minitab running result.

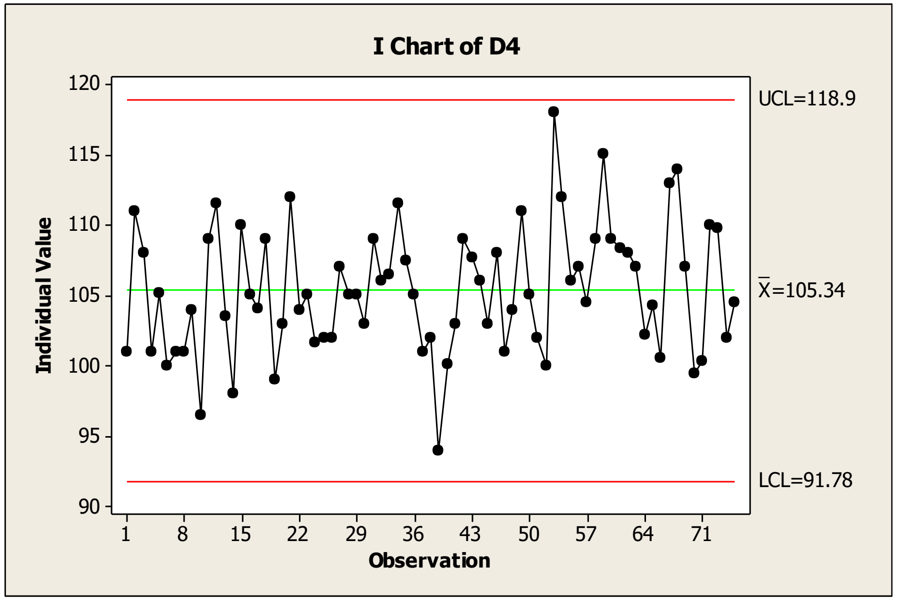

Figure 4.39 The Data Uniformity Test of the 2nd iteration for the Dimension of D4.

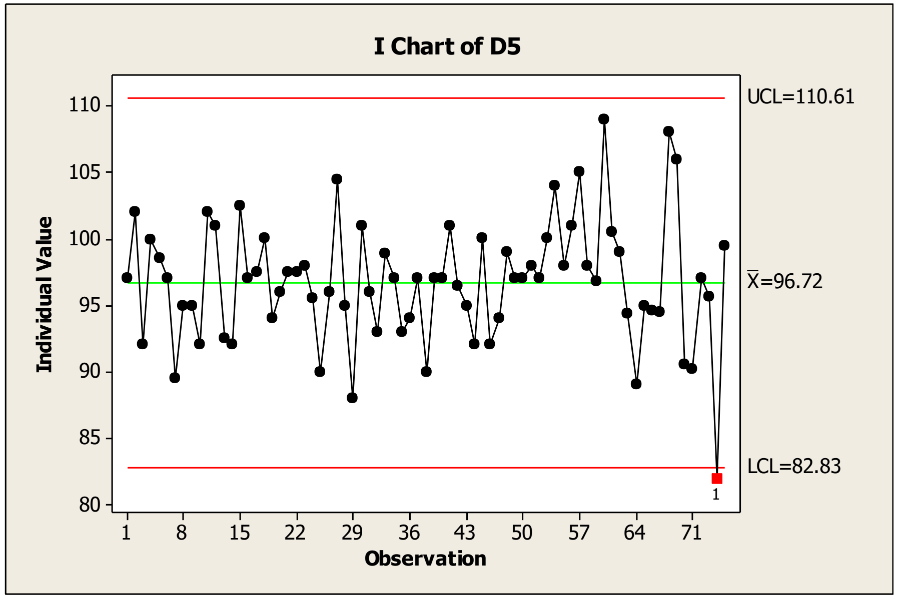

Figure 4.40 The Data Uniformity Test of the 2nd iteration for the Dimension of D5.

Conclusion : The Data from the Dimension of D4 is uniform, the iteration is stopped

Conclusion : The 74th data is out of control (more than 3 times of the standard deviation of the center line).The data uniformity test was continued to the 3rd iteration by issuing the 74th data.

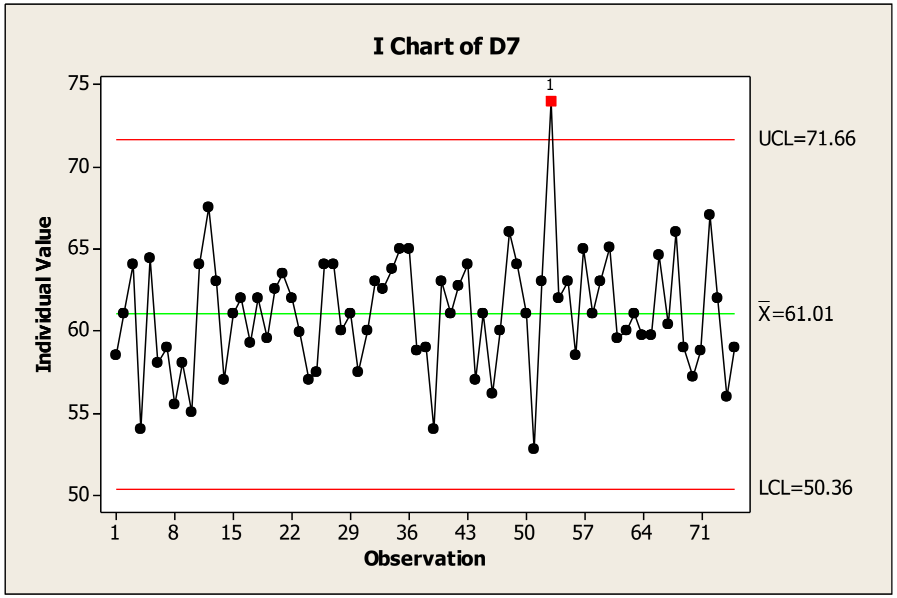

Figure 4.41 The Data Uniformity Test of the 2nd iteration for the Dimension of D7

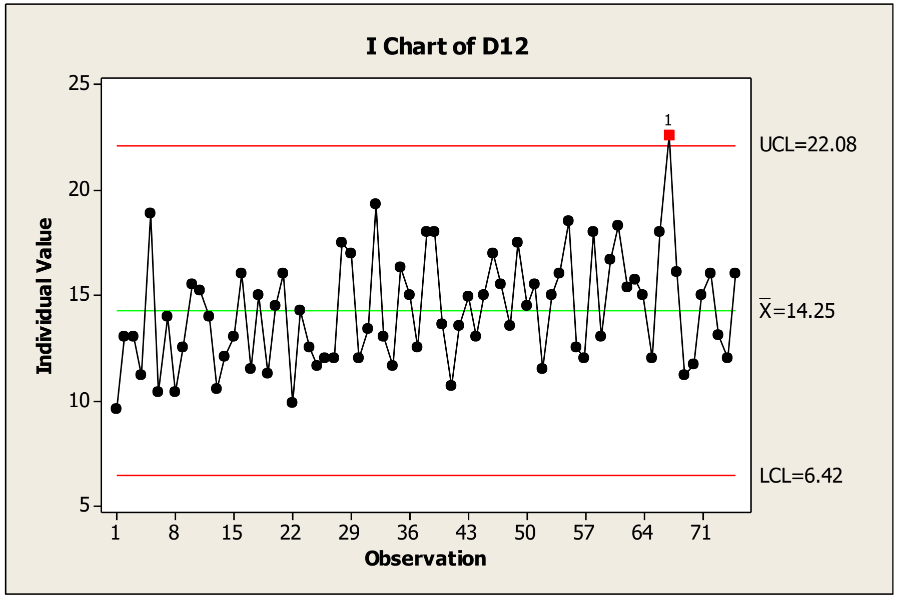

Figure 4.42 The Data Uniformity Test of the 2nd iteration for the Dimension of D12

Conclusion : The 53rd data is out of control (more than 3 times of the standard deviation of the center line). The data uniformity test was continued to the 3rd iteration by issuing the 53rd data.

Conclusion : The 67th data is out of control (more than 3 times of the standard deviation of the center line). The data uniformity test was continued to the 3rd iteration by issuing the 67th data.

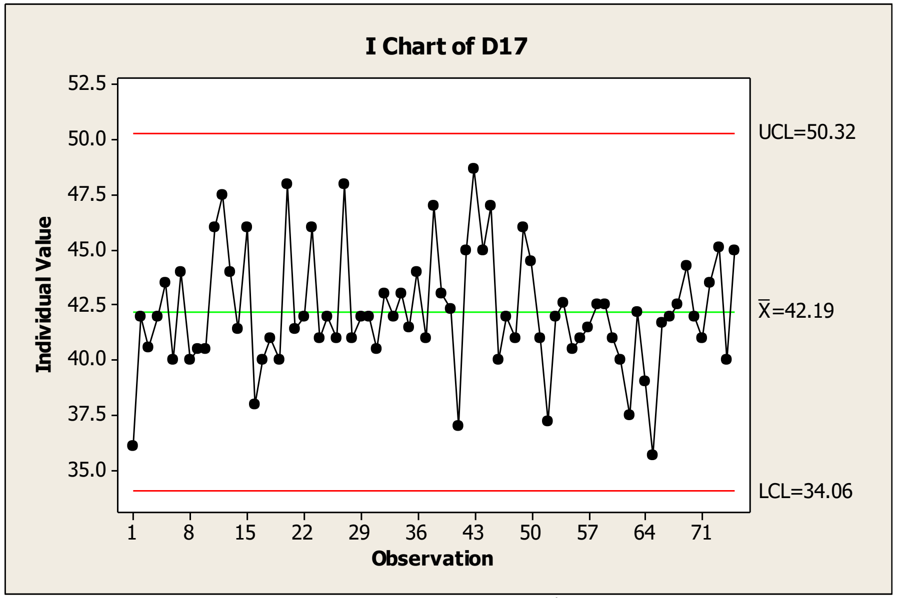

Figure 4.43 The Data Uniformity Test of the 2nd iteration for the Dimension of D17.

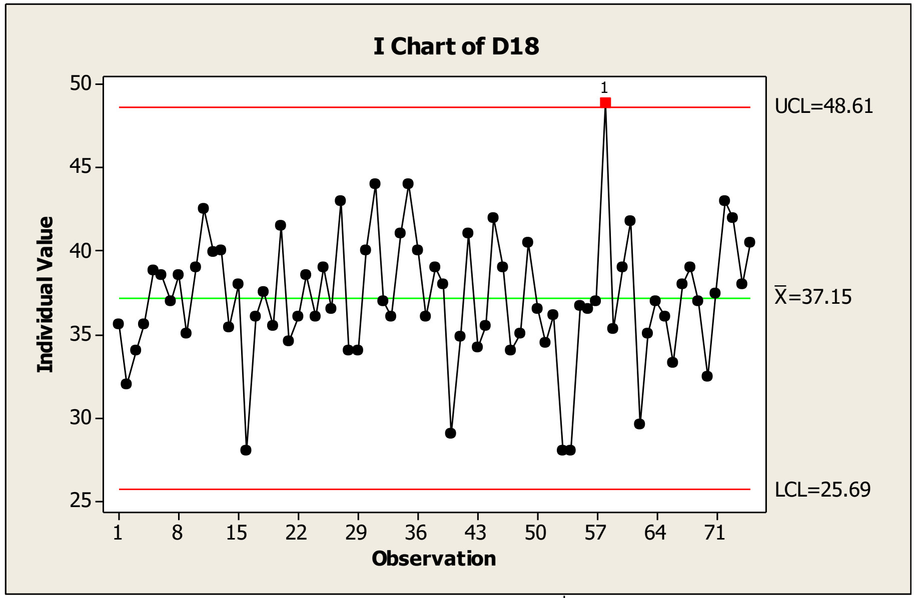

Figure 4.44 The Data Uniformity Test of the 2nd iteration for the Dimension of D18

Conclusion : The Data from the Dimension of D17 is uniform, the iteration is stopped.

Conclusion : The 58th data is out of control (more than 3 times of the standard deviation of the center line).The data uniformity test was continued to the 3rd iteration by issuing the 58th data.

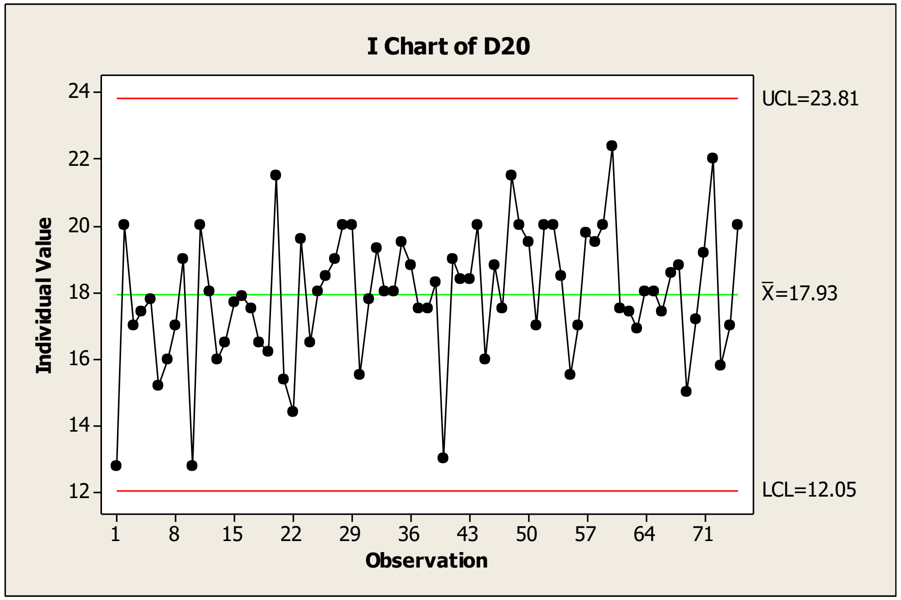

Figure 4.45 The Data Uniformity Test of the 2nd iteration for the Dimension of D20.

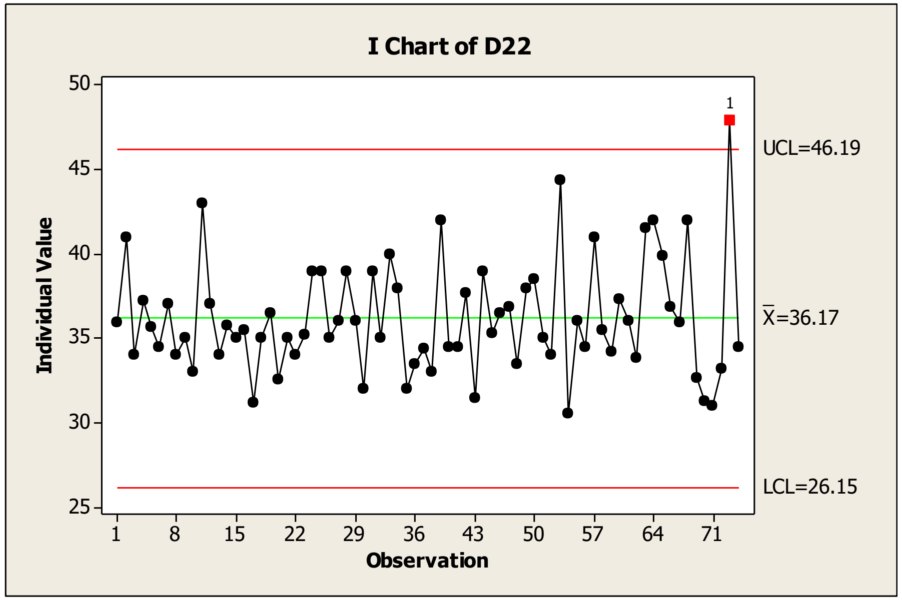

Figure 4.46 The Data Uniformity Test of the 2nd iteration for the Dimension of D22.

Conclusion : The Data from the Dimension of D20 is uniform, the iteration is stopped.

Conclusion : The 73rd data is out of control (more than 3 times of the standard deviation of the center line). The data uniformity test was continued to the 3rd iterationby by using the 73rd data.

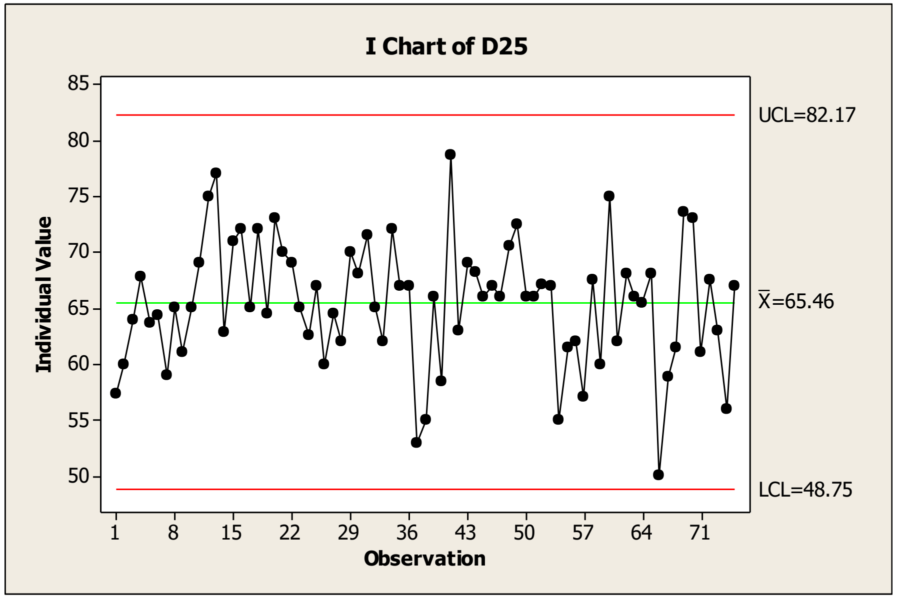

Figure 4.47 The Data Uniformity Test of the 2nd iteration for the Dimension of D25.

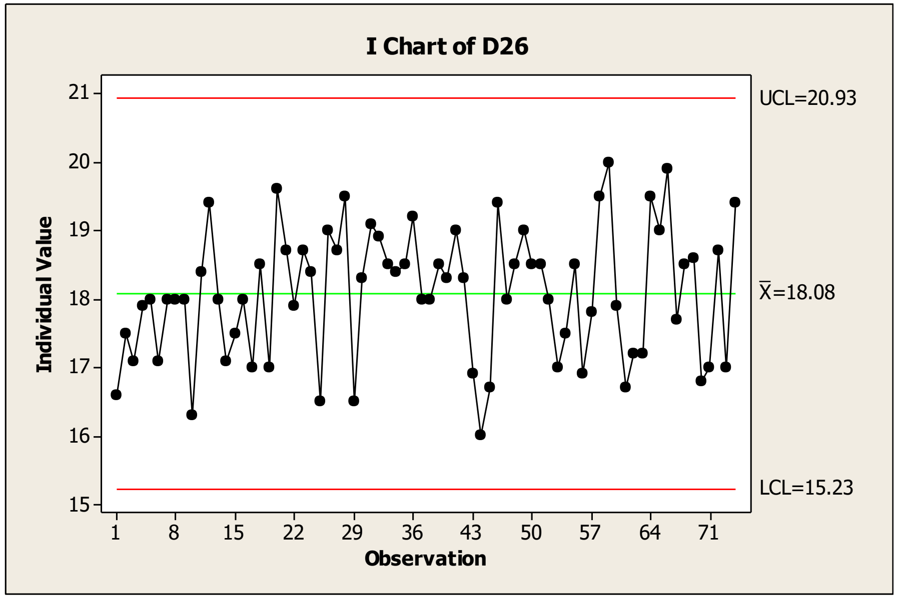

Figure 4.48 The Data Uniformity Test of the 2nd iteration for the Dimension of D26.

Conclusion : The Data from the Dimension of D25 is uniform, the iteration is stopped.

Conclusion : The Data from the Dimension of D26 is uniform, the iteration is stopped.

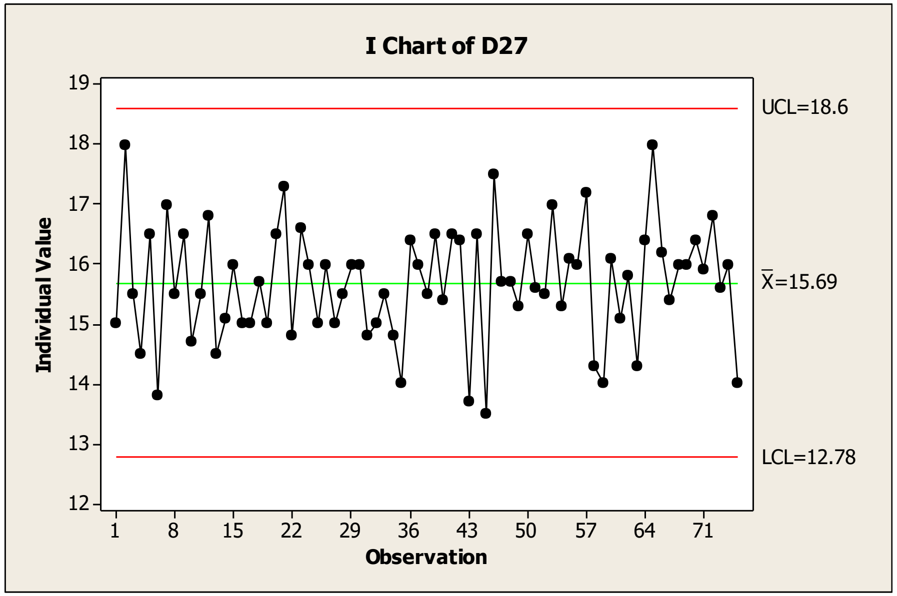

Figure 4.49 The Data Uniformity Test of the 2nd iteration for the Dimension of D27.

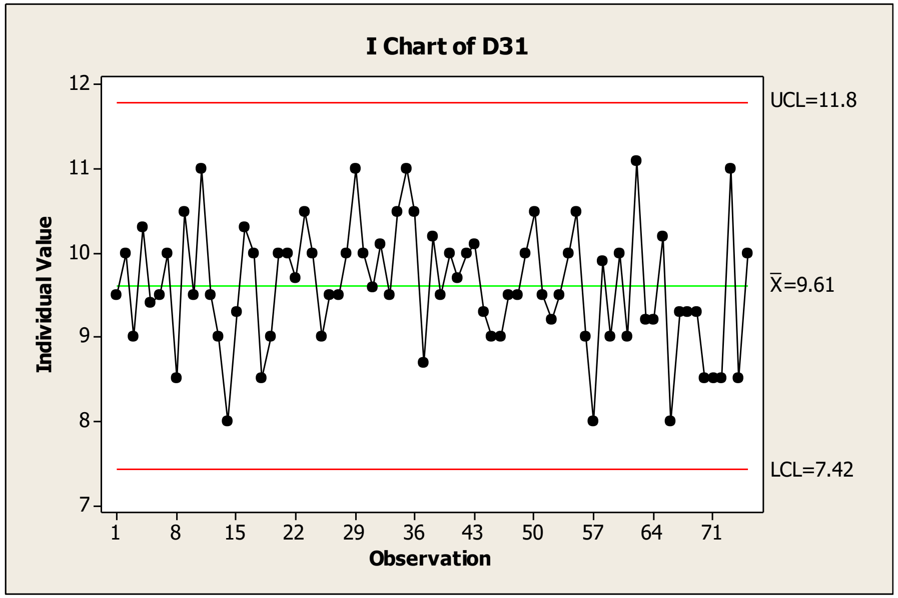

Figure 4.50 The Data Uniformity Test of the 2nd iteration for the Dimension of D31.

Conclusion : The Data from the Dimension of D27 is uniform, the iteration is stopped.

Conclusion : The Data from the Dimension of D31 is uniform, the iteration is stopped.

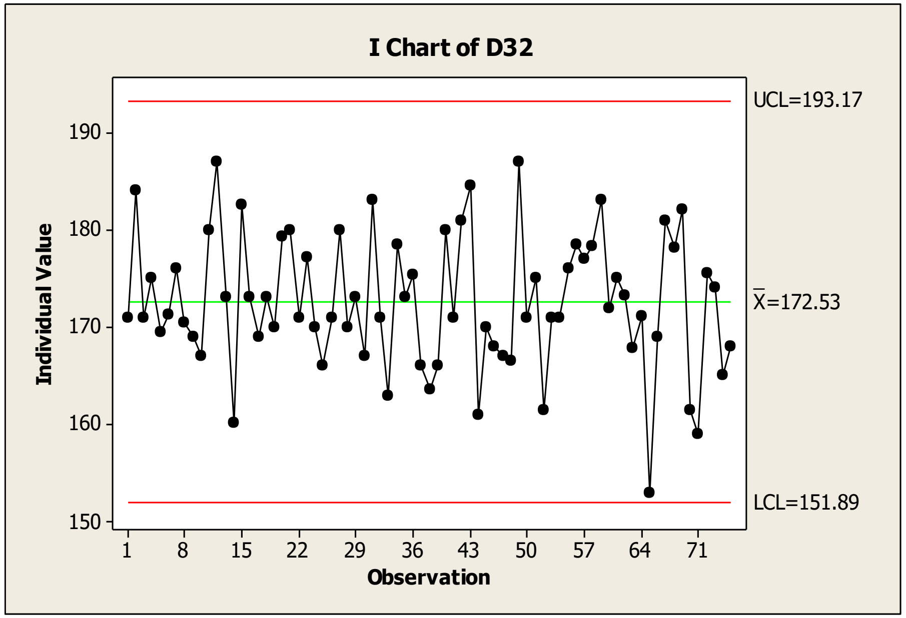

Figure 4.51 The Data Uniformity Test of the 2nd iteration for the Dimension of D32.

Conclusion : The data from the Dimension of D32 is uniform, the iteration is stopped.

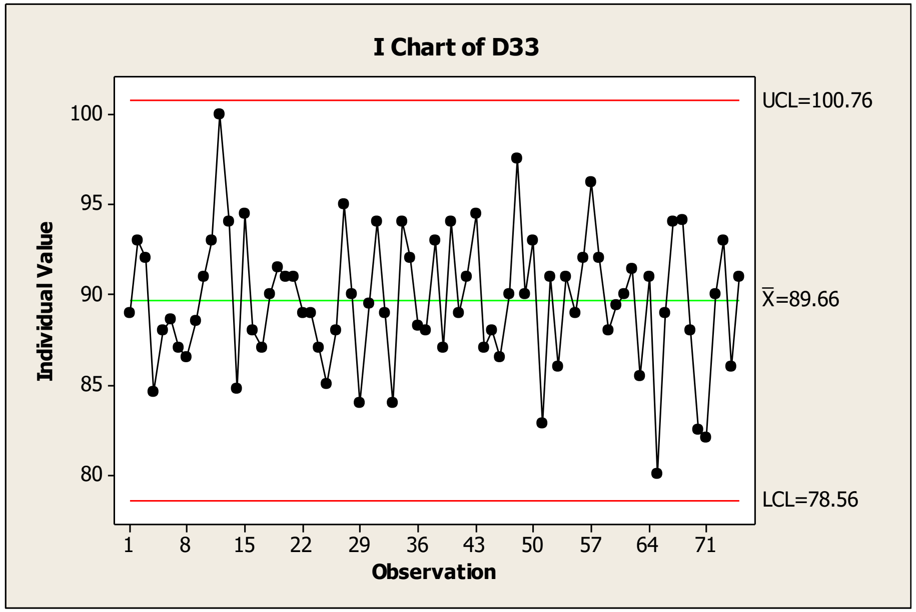

Figure 4.52 The Data Uniformity Test of the 2nd iteration for the Dimension of D33.

Conclusion : The Data from the Dimension of D33 is uniform, the iteration is stopped.

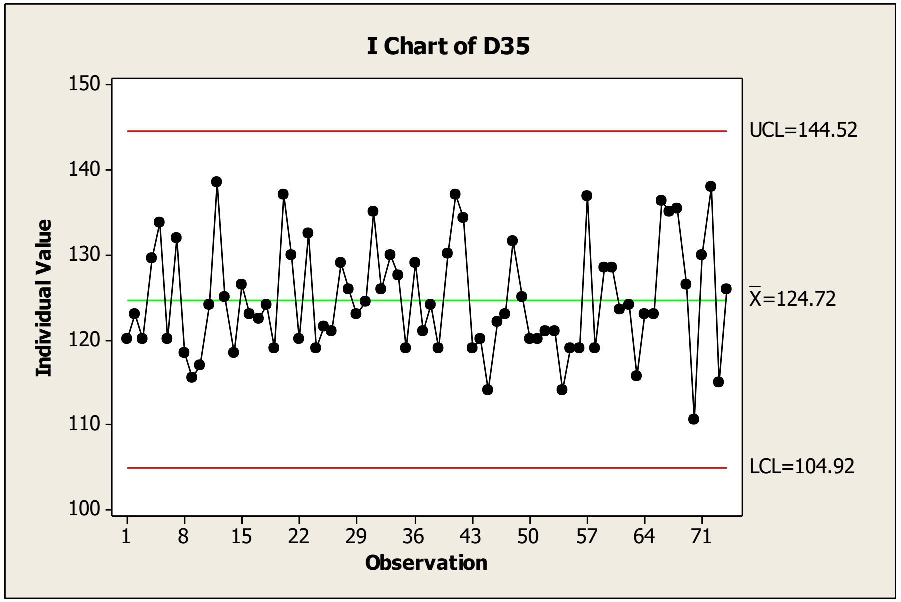

Figure 4.53 The Data Uniformity Test of the 2nd iteration for the Dimension of D35.

Conclusion : The Data from the Dimension of D35 is uniform, the iteration is stopped

The following shows the data recapitulation of data uniformity test results of the 2nd iteration obtained with the help of Minitab 16 software

Table 4.5 The Recapitulation of The 2nd Iteration Data Uniformity Test Results

Dimension	**1**	**2**	**3**	**4**	**etc**	**72**	**73**	**74**	**75**	**N**	**Avg**	**Stdev**	**LCL**	**UCL**	**Conclusion**	**Data Outlier**	**Decision**
D4	101	111	108	101	….	110	109.8	102	104.5	75	105.34	4.52	91.78	118.9	Uniform		Iteration stopped
D5	97	102	92	99.9	….	97	95.6	82	99.5	75	96.72	4.63	82.83	110.61	Not uniform	74	**Continued to the 3rd iteration**
D7	58.5	61	64	54	….	67	62	56	59	75	61.01	3.55	50.36	71.66	Not uniform	53	**Continued to the 3rd iteration**
D12	9.6	13	13	11.2	….	16	13.1	12	16	75	14.25	2.61	6.42	22.08	Not uniform	67	**Continued to the 3rd iteration**
D17	36.1	42	40.6	42	….	43.5	45.1	40	45	75	42.19	2.71	34.06	50.32	Uniform		Iteration stopped
D18	35.6	32	34	35.6	….	43	42	38	40.5	75	37.15	3.82	25.69	48.61	Not uniform	58	**Continued to the 3rd iteration**
D20	12.8	20	17	17.4	….	22	15.8	17	20	75	17.93	1.96	12.05	23.81	Uniform		Iteration stopped
D22	35.9	41	34	37.2	….	33.2	48	34.5		74	36.17	3.34	26.15	46.19	Not uniform	73	**Continued to the 3rd iteration**
D25	57.4	60	64	67.8	….	67.5	63	56	67	75	65.46	5.57	48.75	82.17	Uniform		Iteration stopped
D26	16.6	17.5	17.1	17.9	….	18.7	17	19.4		74	18.08	0.95	15.23	20.93	Uniform		Iteration stopped
D27	15	18	15.5	14.5	….	16.8	15.6	16	14	75	15.69	0.97	12.78	18.6	Uniform		Iteration stopped
D31	9.5	10	9	10.3	….	8.5	11	8.5	10	75	9.61	0.73	7.42	11.8	Uniform		Iteration stopped
D32	171	184	171	175	….	175.5	174	165	168	75	172.53	6.88	151.89	193.17	Uniform		Iteration stopped
D33	89	93	92	84.6	….	90	93	86	91	75	89.66	3.7	78.56	100.76	Uniform		Iteration stopped

Dimension	1	2	3	4	etc	72	73	74	75	N	Avg	Stdev	LCL	UCL	Conclusion	Data Outlier	Decision
D35	120	123	120	129.6	….	138	115	126		74	124.72	6.6	104.92	144.52	Uniform		Iteration stopped

Notes :

- Yellow Color : Data Outliers indicated
- Red Color : Slots for data outliers that have been issued in previous iterations
- Other data Outliers (not included in the table above) are shown in the attachment data.

Based on the result of data uniformity test of the 2nd iteration test of 15 dimensions that outlier at the 1st iteration, there are 5 (about 33.3%) dimensions which was not uniform yet (there is still outlier data) so it needs to be proceed to the 3rd iteration. The dimensions are D5, D7, D12, D18, and D22. The process of data uniformity test of the 3rd iteration wass performed in the same way as the 1st iteration and the 2nd iteration.

The following is an example of data uniformity testof the 3rd iteration for the Dimension of D12 (The thickness of thigh) :

a. The average calculation of the dimension of D12 after the outlier data on the 2nd iteration 2 is issued.

$$\bar{X} = \frac{\sum_{i=1}^{N} X_i}{N}$$

Where,
$\bar{X}$ = the average
X_i = the value of the data to-i
N = the amount of the data

$$\bar{X} = \frac{9.6 + 13 + 13 + \cdots + 13.1 + 12 + 16}{74}$$
$$\bar{X} = \frac{1046.4}{74}$$
$$\bar{X} = 14.14\ cm$$

b. The Calculation of the standard deviation

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(X_i - \bar{X})^2}{N-1}}$$

Where,
σ = the standard deviation sample
X_i = the value of the data to-i
$\bar{X}$ = the average
N = the number of samples

$$\sigma = \sqrt{\frac{(9.6 - 14.14)^2 + (13 - 14.14)^2 + \cdots + (12 - 14.14)^2 + (16 - 14.14)^2}{74-1}}$$
$$\sigma = \sqrt{\frac{20.61 + 1.30 + \cdots + 4.58 + 3.46}{73}}$$

$$\sigma = \sqrt{\frac{435.258}{73}}$$

$$\sigma = \sqrt{5.96244}$$

$$\sigma = 2.44 \text{ cm}$$

c.The Determination of Lower Control Limit (LCL) and Upper Control Limit (UCL) data dimension of D12 was done by using equation 2.4 and 2.5, same as the 1st iteration and the 2nd iteration.

$$LCL = \bar{X} - 3\sigma$$

$$LCL = 14.14 - 3 \times 2.44$$

$$LCL = 6.882 \text{ cm}$$

and

$$UCL = \bar{X} + 3\sigma$$

$$UCL = 14.14 + 3 \times 2.44$$

$$UCL = 21.46 \text{ cm}$$

Furthermore, the parameter of average, standard deviation, lower control limit and upper control limit for other dimensions were calculated by using the same formula as dimension of D12. Table 4.6 shows the recap calculation of the data uniformity test value parameter for the 3rd iteration :

Table 4.6 The Data Uniformity Test Parameter Data Recap of the 3rd Iteration

Dimension	1	2	3	4	etc	71	72	73	74	N	Avg	Stdev	LCL	UCL
D5	97	102	92	99.9	....	90.2	97	95.6	99.5	74	96.92	4.33	83.93	109.9
D7	58.5	61	64	54	....	67	62	56	59	74	60.84	3.23	51.15	70.53
D12	9.6	13	13	11.2	....	16	13.1	12	16	74	14.14	2.44	6.82	21.46
D18	35.6	32	34	35.6	....	43	42	38	40.5	74	36.99	3.59	26.22	47.76
D22	35.9	41	34	37.2	....	31	33.2	34.5		73	36.01	3.06	26.83	45.19

Same as the process on the 1st iteration and the 2nd iteration, the data uniformity test of the 3rd iteration test was done by using Minitab 16 software. Here is the Individual Control Chart graph obtained from the Minitab running result.

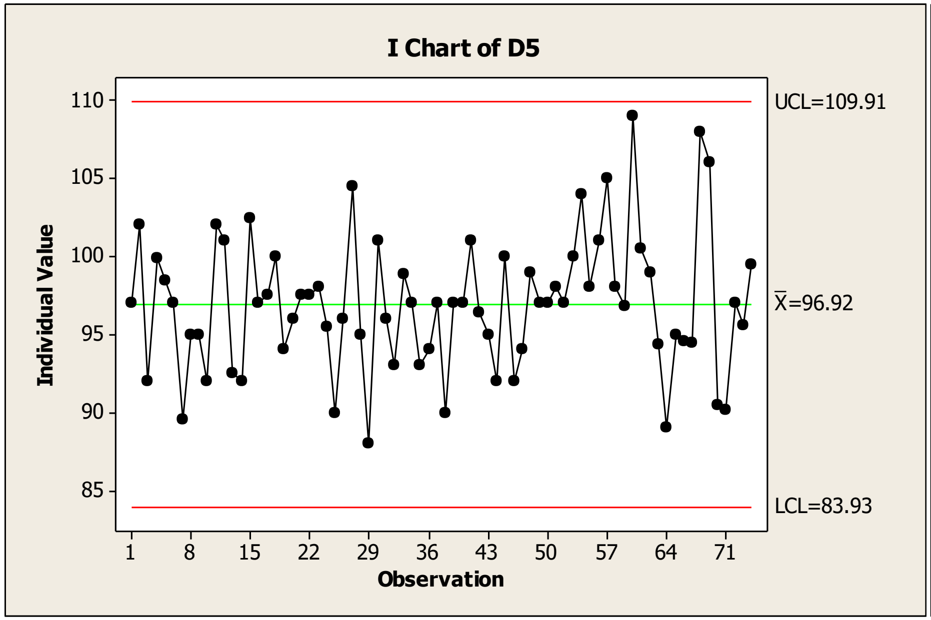

Figure 4.54 The Data Uniformity Test of the 3rd iteration for Dimension D5.

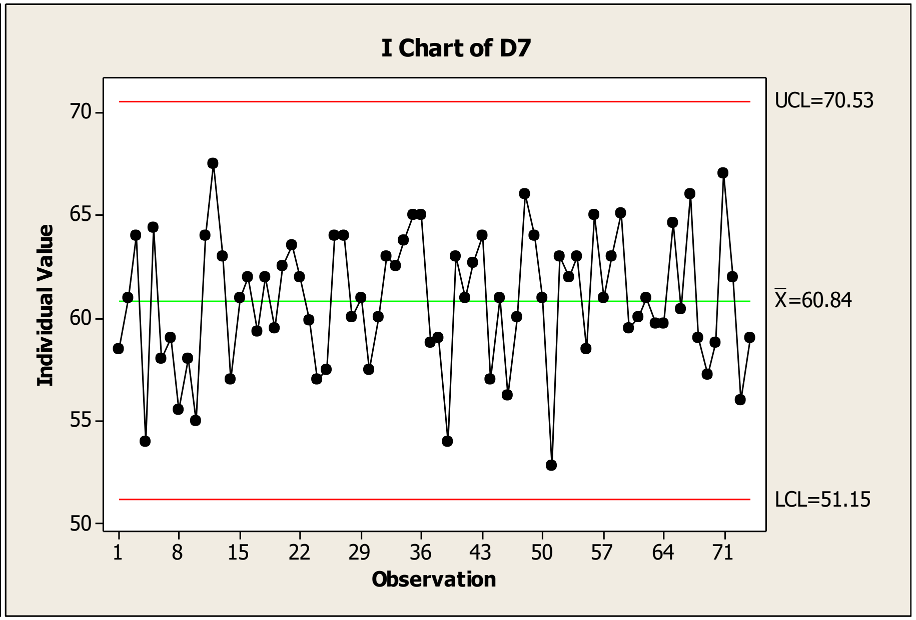

Figure 4.55 The Data Uniformity Test of the 3rd iteration for the Dimension of D7.

Conclusion : The Data from the Dimension of D5 is uniform, the iteration is stopped.

Conclusion : The Data from the Dimension of D7 is uniform, the iteration is stopped

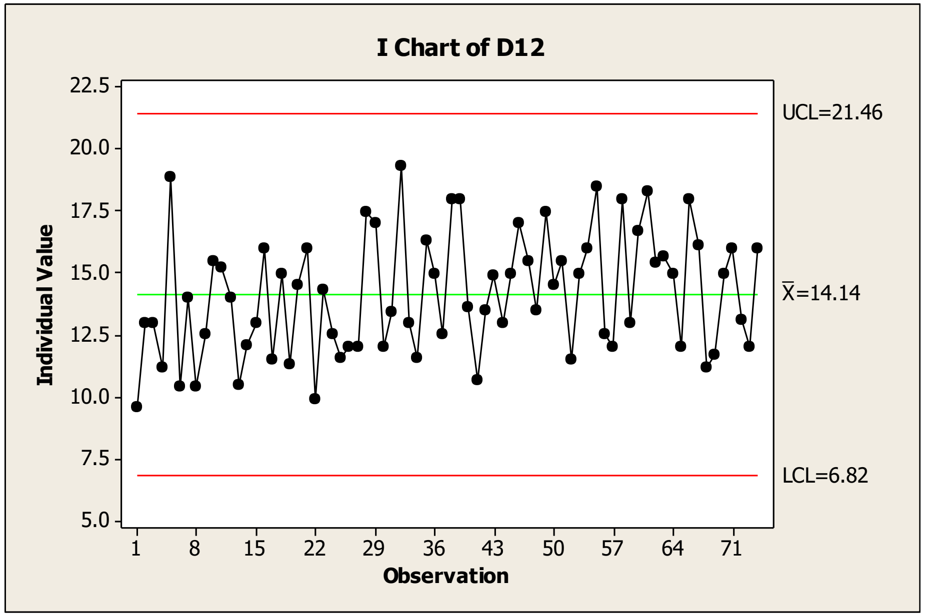

Figure 4.56 The Data Uniformity Test of the 3rd iteration for the Dimension of D12.

Conclusion : The Data from the Dimension of D12 is uniform, the iteration is stopped.

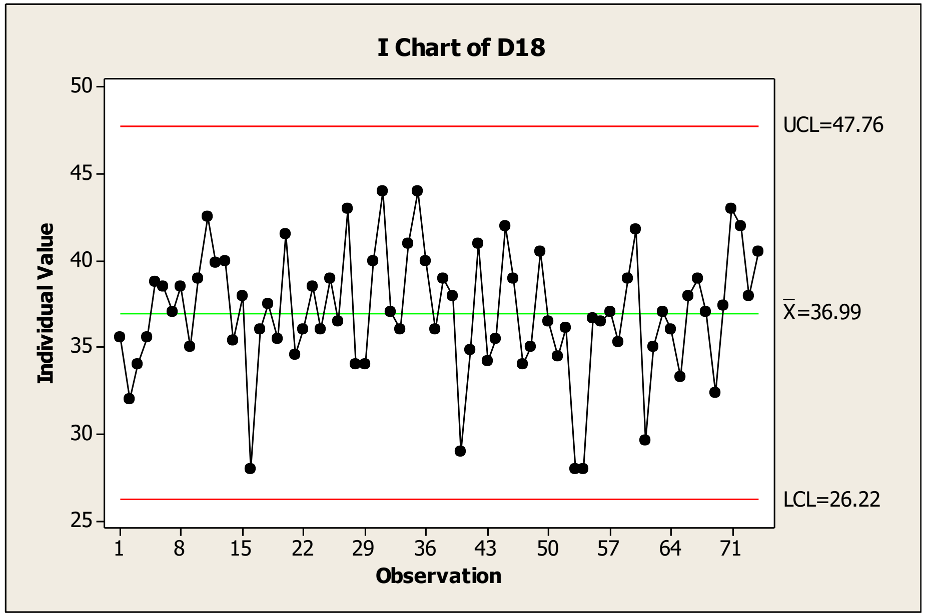

Figure 4.57 The Data Uniformity Test of the 3rd iteration for the Dimension of D18.

Conclusion : The Data from the Dimension of D18 is uniform, the iteration is stopped.

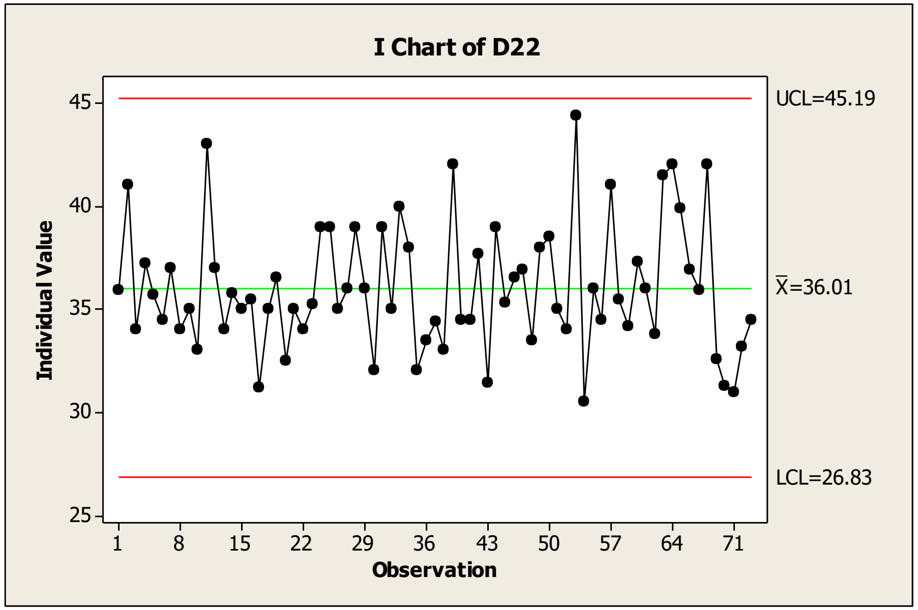

Figure 4.58 The Data Uniformity Test of the 3rd iteration for the Dimension of D22.

Conclusion : The Data from the Dimension of D22 is uniform, the iteration is stopped.

The following table shows the results of the uniformity test of the 3rd iteration results obtained with the help of Minitab 16 software:

Table 4.7 The Recapitulation of The 3rd Iteration Data Uniformity Test Results

Dimension	1	2	3	4	etc	71	72	73	74	N	Avg	Stdev	LCL	UCL	Conclusion	Data Outlier	Decision
D5	97	102	92	99.9	....	90.2	97	95.6	99.5	74	96.92	4.33	83.93	109.91	Uniform	-	Iteration stopped
D7	58.5	61	64	54	....	67	62	56	59	74	60.84	3.23	51.15	70.53	Uniform	-	Iteration stopped
D12	9.6	13	13	11.2	....	16	13.1	12	16	74	14.14	2.44	6.82	21.46	Uniform	-	Iteration stopped
D18	35.6	32	34	35.6	....	43	42	38	40.5	74	36.99	3.59	26.22	47.76	Uniform	-	Iteration stopped
D22	35.9	41	34	37.2	....	31	33.2	34.5		73	36.01	3.06	26.83	45.19	Uniform	-	Iteration stopped

After three iterations, all data from D1 - D36 dimension are within the limits of LCL and UCL so, it can be said that the data is uniform. The following table shows a recap of the data uniformity test results from the 1st Iteration to the 3rd iterationof dimensions D1 - D36:

Table 4.8 The Recap Data Test Results of Data Uniformity Test from The 1st Iteration to 3rd Iteration

Dimension	**1**	**2**	**3**	**4**	**etc**	**73**	**74**	**75**	**76**	**N**	**Avg**	**Stdev**
D1	166	177	173.5	167.7	...	172	169.8	164	165.5	76	168.67	5.36
D2	156.5	164	160	156.2	...	160	158.1	150	154	76	156.78	5.64
D3	139.5	146	144	139.3	...	144	146.2	132	139.5	76	140.87	5.34
D4	101	111	108	101	...	109.8	102	104.5		75	105.34	4.52
D5	97	102	92	99.9	...	95.6	99.5			74	96.92	4.33
D6	65	89	91	83	...	76	72.3	70	72	76	74.8	7.98
D7	58.5	61	64	54	...	56	59			74	60.84	3.23
D8	85	92	87	89	...	92.5	88.6	90	94	76	88.9	3.79
D9	75	79	78	78	...	83	77.6	74	83	76	78.28	4.09
D10	58	62	60	61.5	...	63	58.2	62	68	76	60.65	4.25
D11	21.5	25	20.4	28.8	...	20	21.5	19	30.5	76	22.56	3.29
D12	9.6	13	13	11.2	...	12	16			74	14.14	2.44

Dimension	1	2	3	4	etc	73	74	75	76	N	Avg	Stdev
D13	54.7	55	65.3	63	...	58	53	52	53	76	57.17	3.57
D14	49.8	41	33	46	...	44	39.8	40	42	76	46.33	4.64
D15	52.6	56	54	51.3	...	51	57	49	53	76	51.89	2.52
D16	42	48	42	39	...	40	42	42	41.5	76	41.65	2.33
D17	36.1	42	40.6	42	...	45.1	40	45		75	42.19	2.71
D18	35.6	32	34	35.6	...	38	40.5			74	36.99	3.59
D19	26.7	35	28	33.5	...	34	31.8	32	38	76	33.13	4.51
D20	12.8	20	17	17.4	...	15.8	17	20		75	17.93	1.96
D21	14.2	15	17	16.3	...	27	21.3	20	19.6	76	18.68	2.95
D22	35.9	41	34	37.2	...	34.5				73	36.01	3.06
D23	43	50	47	40.5	...	46	47.3	42	44.5	76	43.53	4.61
D24	76	73.5	73.6	76	...	75	76.2	75	71	76	75.54	3.74
D25	57.4	60	64	67.8	...	63	56	67		75	65.46	5.57
D26	16.6	17.5	17.1	17.9	...	17	19.4			74	18.08	0.95
D27	15	18	15.5	14.5	...	15.6	16	14		75	15.69	0.97
D28	18	19	18	18.2	...	18.5	19.1	16.5	18.5	76	18.71	1.31
D29	9.1	9	8.5	8.9	...	8	8.5	7.9	10	76	8.68	0.81
D30	24.5	27	25	23.7	...	24.5	25.9	23.5	25	76	24.98	1.28
D31	9.5	10	9	10.3	...	11	8.5	10		75	9.61	0.73
D32	171	184	171	175	...	174	165	168		75	172.53	6.88
D33	89	93	92	84.6	...	93	86	91		75	89.66	3.7
D34	198	213	201	180.3	...	200	218	189	208	76	203.66	8.99
D35	120	123	120	129.6	...	115	126			74	124.72	6.6
D36	69	70	66	71	...	66	74.2	63	69	76	71.14	5.39

Note :
Red color : The outlier data that has been removed at the 1st iteration to the 3rd iteration

4.2.2 Data adequacy test

Data obtained from the data uniformity test will be proceed to the data adequacy test. Data adequacy test is done to determine whether the amount of data taken has sufficient amount of data that should be taken or not. The data taken is sufficient if the amount of data (N) taken is greater than the amount of data that should be retrieved (N'). It is vice versa if N is smaller than N' then the data is said to be not enough so it needs additional data. Here is a formula used in the data adequacy test :

$$N' = \left[\frac{Z.S}{\bar{X}\,k}\right]^2$$

Where
N' = the number of observations (data) that should be taken
Z = Index of confidence level (95% confidence level = 2)
S = the standard deviation of data
$\bar{X}$ = the average data after uniformity
k = the error rate (5%)

Here is a calculation of N' for the dimension of D1 (the height of body) using a 95% confidence level.

$$N' = \left[\frac{Z.S}{\bar{X}\,k}\right]^2$$

$$N' = \left[\frac{2 \times 5.36}{1688.67 \times 0.05}\right]^2$$

$$N' = \left[\frac{10.72}{88.43}\right]^2$$

$$N' = 1.62$$

$$N' = \sim 2$$

From the calculation results obtained, the amount of data that should be taken (N') as much as 2, while the amount of data taken in this study is 76 data (Data N used is the amount of data after the data uniformity test and data adequacy test). Therefore, it can be said that the data dimension D1 is enough because the amount of data taken in this research (N) is greater than the amount of data that should be taken (N').

The data adequacy test for dimension of D2 - D36 is performed using the same formula as dimension of D1. The following is a recap of the data adequacy test from dimension of D1 - D36.

Table 4.9 The Recap of The Data Adequacy Test

Dimension	**1**	**2**	**3**	**4**	**etc**	**73**	**74**	**75**	**76**	**N**	**Avg**	**Stdev**	**Z x S**	**Avg x k**	**N'**	**Conclusion**
D1	166	177	173.5	167.7	...	172	169.8	164	165.5	76	168.67	5.36	10.72	8.43	1.62	N is greater than N', Enough Data
D2	156.5	164	160	156.2	...	160	158.1	150	154	76	156.78	5.64	11.28	7.84	2.07	N is greater than N', Enough Data
D3	139.5	146	144	139.3	...	144	146.2	132	139.5	76	140.87	5.34	10.68	7.04	2.3	N is greater than N', Enough Data
D4	101	111	108	101	...	109.8	102	104.5		75	105.34	4.52	9.04	5.27	2.95	N is greater than N', Enough Data
D5	97	102	92	99.9	...	95.6	99.5			74	96.92	4.33	8.66	4.85	3.19	N is greater than N', Enough Data
D6	65	89	91	83	...	76	72.3	70	72	76	74.8	7.98	15.96	3.74	18.21	N is greater than N', Enough Data
D7	58.5	61	64	54	...	56	59			74	60.84	3.23	6.46	3.04	4.51	N is greater than N', Enough Data
D8	85	92	87	89	...	92.5	88.6	90	94	76	88.9	3.79	7.58	4.45	2.91	N is greater than N', Enough Data
D9	75	79	78	78	...	83	77.6	74	83	76	78.28	4.09	8.18	3.91	4.37	N is greater than N', Enough Data
D10	58	62	60	61.5	...	63	58.2	62	68	76	60.65	4.25	8.5	3.03	7.86	N is greater than N', Enough Data
D11	21.5	25	20.4	28.8	...	20	21.5	19	30.5	76	22.56	3.29	6.58	1.13	34.03	N is greater than N', Enough Data

Dimension	1	2	3	4	etc	73	74	75	76	N	Avg	Stdev	Z x S	Avg x k	N'	Conclusion
D12	9.6	13	13	11.2	...	12	16			74	14.14	2.44	4.88	0.71	47.64	N is greater than N', Enough Data
D13	54.7	55	65.3	63	...	58	53	52	53	76	57.17	3.57	7.14	2.86	6.24	N is greater than N', Enough Data
D14	49.8	41	33	46	...	44	39.8	40	42	76	46.33	4.64	9.28	2.32	16.05	N is greater than N', Enough Data
D15	52.6	56	54	51.3	...	51	57	49	53	76	51.89	2.52	5.04	2.59	3.77	N is greater than N', Enough Data
D16	42	48	42	39	...	40	42	42	41.5	76	41.65	2.33	4.66	2.08	5.01	N is greater than N', Enough Data
D17	36.1	42	40.6	42	...	45.1	40	45		75	42.19	2.71	5.42	2.11	6.6	N is greater than N', Enough Data
D18	35.6	32	34	35.6	...	38	40.5			74	36.99	3.59	7.18	1.85	15.07	N is greater than N', Enough Data
D19	26.7	35	28	33.5	...	34	31.8	32	38	76	33.13	4.51	9.02	1.66	29.65	N is greater than N', Enough Data
D20	12.8	20	17	17.4	...	15.8	17	20		75	17.93	1.96	3.92	0.9	19.12	N is greater than N', Enough Data
D21	14.2	15	17	16.3	...	27	21.3	20	19.6	76	18.68	2.95	5.9	0.93	39.9	N is greater than N', Enough Data
D22	35.9	41	34	37.2	...	34.5				73	36.01	3.06	6.12	1.8	11.55	N is greater than N', Enough Data
D23	43	50	47	40.5	...	46	47.3	42	44.5	76	43.53	4.61	9.22	2.18	17.95	N is greater than N', Enough Data
D24	76	73.5	73.6	76	...	75	76.2	75	71	76	75.54	3.74	7.48	3.78	3.92	N is greater than N', Enough Data

Dimension	1	2	3	4	etc	73	74	75	76	N	Avg	Stdev	Z x S	Avg x k	N'	Conclusion
D25	57.4	60	64	67.8	...	63	56	67		75	65.46	5.57	11.14	3.27	11.58	N is greater than N', Enough Data
D26	16.6	17.5	17.1	17.9	...	17	19.4			74	18.08	0.95	1.9	0.9	4.42	N is greater than N', Enough Data
D27	15	18	15.5	14.5	...	15.6	16	14		75	15.69	0.97	1.94	0.78	6.12	N is greater than N', Enough Data
D28	18	19	18	18.2	...	18.5	19.1	16.5	18.5	76	18.71	1.31	2.62	0.94	7.84	N is greater than N', Enough Data
D29	9.1	9	8.5	8.9	...	8	8.5	7.9	10	76	8.68	0.81	1.62	0.43	13.93	N is greater than N', Enough Data
D30	24.5	27	25	23.7	...	24.5	25.9	23.5	25	76	24.98	1.28	2.56	1.25	4.2	N is greater than N', Enough Data
D31	9.5	10	9	10.3	...	11	8.5	10		75	9.61	0.73	1.46	0.48	9.23	N is greater than N', Enough Data
D32	171	184	171	175	...	174	165	168		75	172.53	6.88	13.76	8.63	2.54	N is greater than N', Enough Data
D33	89	93	92	84.6	...	93	86	91		75	89.66	3.7	7.4	4.48	2.72	N is greater than N', Enough Data
D34	198	213	201	180.3	...	200	218	189	208	76	203.66	8.99	17.98	10.18	3.12	N is greater than N', Enough Data
D35	120	123	120	129.6	...	115	126			74	124.72	6.6	13.2	6.24	4.48	N is greater than N', Enough Data
D36	69	70	66	71	...	66	74.2	63	69	76	71.14	5.39	10.78	3.56	9.18	N is greater than N', Enough Data

Based on the results of the data adequacy test that has been done, the amount of data D1 - D36 taken in this study (N) has sufficient amount of data that should be taken (N') so additional data is not needed.

4.2.3 The selection of dimension data used

Based on the results of data uniformity test and data adequacy test that has been done in the previous section, it can be concluded that the anthropometric data dimensions of the Indonesia people used in this research is valid to be used in the design of Bridge Control Console for Landing Ship Tank. Landing Ship Tank is a ship used as an amphibious tank carrier from the middle of the ocean. In Indonesia, Landing Ship Tank is operated by the TNI (Indonesian National Army). One of the requirements to become TNI is a minimum height of 165cm for men. While in the data used in this research, there are still respondents whose height is less than 165 cm. Therefore, it is necessary to select the dimensions that can represent the minimum height requirements to enter TNI.

Selection of dimensions to be used in this research was done by searching the value of the height of body dimension (D1) through trial & error. The search for a percentile value that gives a height value of 165 cm was performed by using the average excel formula + normsinv (percentile) x standard deviation. From the calculation results obtained, the value of the represented percentile is 25% which shows the value of height of 165 cm. The following chart shows the visualization approach used to estimate the height of body population of TNI in range of percentage.

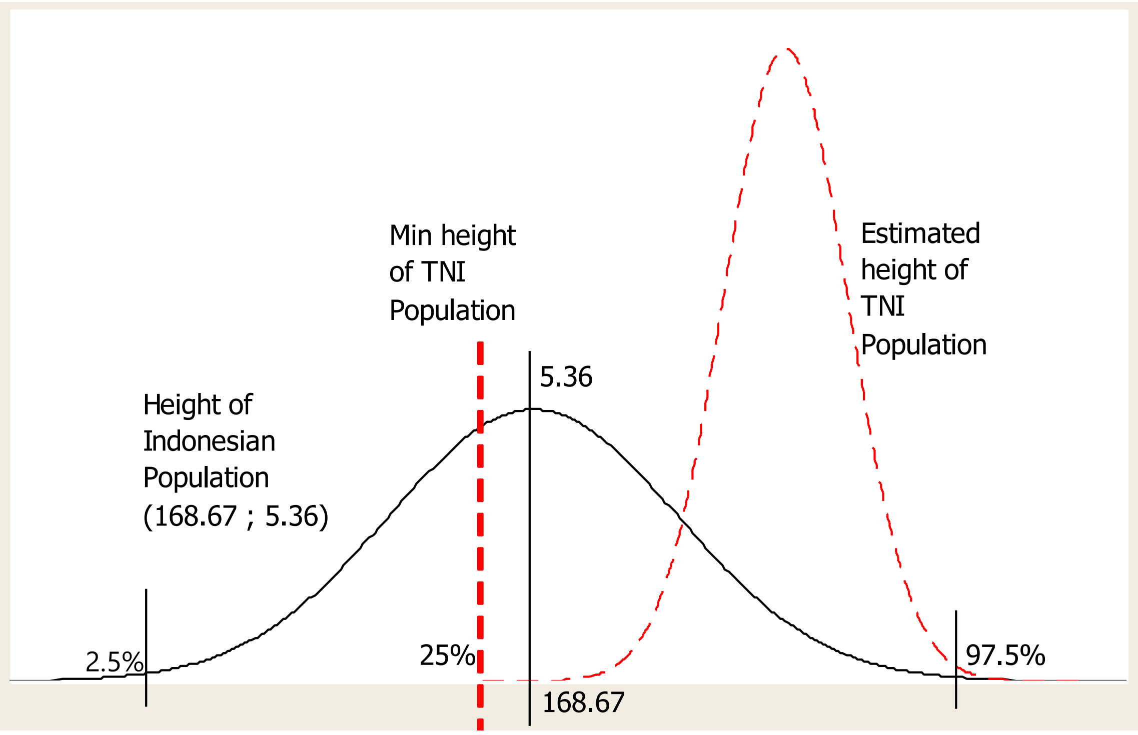

Figure 4.59 Visualization of Percentile Range on TNI Height Estimation

From the picture above, it can be seen that the height of 165 cm is in the the 25th-percentile of the population of Indonesia. Therefore, it can be said that the range of the TNI population is in the range of the 25th percentile upwards, so a variety of the 25th percentile down will be ignored in this research because it does not meet the criteria of the height of TNI.

4.2.4 The determination of percentile

Based on the results of the data selection dimensions that have been done in the previous stage, it is noted that the height of 165 cm is in the range of the 25th percentile. Therefore, in this research, the calculation of the 25th percentile and above. Here is a formula to calculate the value of X (X = the value of the variable searched, can represent anybody dimension) by using a specified percentile amount.

$$X = \bar{X} + Z \times S$$

Where,
X = The Value searched
$\bar{X}$ = The average value of the dimensions after the data uniformity test and the data adequacy test
Z = The inverse value of the normal distribution based on the specified percentile
S = The standard deviation dimension after the data uniformity test and the data adequacy test

The following calculation shows the example of calculating the value of X (height of body / D1) by using the 25th percentile.

$$X = 168.67 + (-0.67449) \times 5.36$$
$$X = 168.67 - 3.61527$$
$$X = 165.05473 \text{ cm}$$
$$X \sim 165.05 \text{ cm}$$

The calculation of the X value for another dimension was used by using the same formula as the calculation of D1. The following table shows the determination of X value according to the specified percentile value.

Table 4.10 Determination of X Value

Dimension	1	2	3	4	etc	73	74	75	76	N	Avg	Stdev	25%	27.50%	30%	50%	90%	95%	97.50%
D1	166	177	173.5	167.7	...	172	169.8	164	165.5	76	168.67	5.36	165.05	165.47	165.86	168.67	175.54	177.49	179.18
D2	156.5	164	160	156.2	...	160	158.1	150	154	76	156.78	5.64	152.98	153.41	153.82	156.78	164.01	166.06	167.84
D3	139.5	146	144	139.3	...	144	146.2	132	139.5	76	140.87	5.34	137.27	137.68	138.07	140.87	147.71	149.65	151.34
D4	101	111	108	101	...	109.8	102	104.5		75	105.34	4.52	102.29	102.64	102.97	105.34	111.13	112.77	114.2
D5	97	102	92	99.9	...	95.6	99.5			74	96.92	4.33	94	94.33	94.65	96.92	102.47	104.04	105.41
D6	65	89	91	83	...	76	72.3	70	72	76	74.8	7.98	69.42	70.03	70.62	74.8	85.03	87.93	90.45
D7	58.5	61	64	54	...	56	59			74	60.84	3.23	58.66	58.91	59.15	60.84	64.98	66.15	67.18
D8	85	92	87	89	...	92.5	88.6	90	94	76	88.9	3.79	86.34	86.63	86.91	88.9	93.76	95.13	96.33
D9	75	79	78	78	...	83	77.6	74	83	76	78.28	4.09	75.52	75.84	76.14	78.28	83.52	85.01	86.3
D10	58	62	60	61.5	...	63	58.2	62	68	76	60.65	4.25	57.78	58.11	58.42	60.65	66.1	67.64	68.98
D11	21.5	25	20.4	28.8	...	20	21.5	19	30.5	76	22.56	3.29	20.34	20.59	20.83	22.56	26.78	27.97	29.01
D12	9.6	13	13	11.2	...	12	16			74	14.14	2.44	12.49	12.68	12.86	14.14	17.27	18.15	18.93
D13	54.7	55	65.3	63	...	58	53	52	53	76	57.17	3.57	54.76	55.04	55.3	57.17	61.75	63.04	64.17
D14	49.8	41	33	46	...	44	39.8	40	42	76	46.33	4.64	43.2	43.56	43.9	46.33	52.28	53.96	55.43
D15	52.6	56	54	51.3	...	51	57	49	53	76	51.89	2.52	50.19	50.38	50.57	51.89	55.12	56.04	56.83
D16	42	48	42	39	...	40	42	42	41.5	76	41.65	2.33	40.08	40.26	40.43	41.65	44.64	45.48	46.22
D17	36.1	42	40.6	42	...	45.1	40	45		75	42.19	2.71	40.36	40.57	40.77	42.19	45.66	46.65	47.51
D18	35.6	32	34	35.6	...	38	40.5			74	36.99	3.59	34.57	34.84	35.11	36.99	41.59	42.9	44.03
D19	26.7	35	28	33.5	...	34	31.8	32	38	76	33.13	4.51	30.09	30.43	30.76	33.13	38.91	40.55	41.97
D20	12.8	20	17	17.4	...	15.8	17	20		75	17.93	1.96	16.61	16.76	16.9	17.93	20.44	21.15	21.78
D21	14.2	15	17	16.3	...	27	21.3	20	19.6	76	18.68	2.95	16.69	16.92	17.13	18.68	22.46	23.53	24.47
D22	35.9	41	34	37.2	...	34.5				73	36.01	3.06	33.95	34.18	34.41	36.01	39.93	41.04	42.01
D23	43	50	47	40.5	...	46	47.3	42	44.5	76	43.53	4.61	40.42	40.77	41.11	43.53	49.44	51.11	52.57
D24	76	73.5	73.6	76	...	75	76.2	75	71	76	75.54	3.74	73.02	73.3	73.58	75.54	80.33	81.69	82.88

Dimension	1	2	3	4	etc	73	74	75	76	N	Avg	Stdev	25%	27.50%	30%	50%	90%	95%	97.50%
D25	57.4	60	64	67.8	...	63	56	67		75	65.46	5.57	61.7	62.13	62.54	65.46	72.6	74.62	76.38
D26	16.6	17.5	17.1	17.9	...	17	19.4			74	18.08	0.95	17.44	17.51	17.58	18.08	19.3	19.64	19.95
D27	15	18	15.5	14.5	...	15.6	16	14		75	15.69	0.97	15.04	15.11	15.18	15.69	16.93	17.29	17.6
D28	18	19	18	18.2	...	18.5	19.1	16.5	18.5	76	18.71	1.31	17.83	17.93	18.02	18.71	20.39	20.86	21.28
D29	9.1	9	8.5	8.9	...	8	8.5	7.9	10	76	8.68	0.81	8.13	8.2	8.26	8.68	9.72	10.01	10.27
D30	24.5	27	25	23.7	...	24.5	25.9	23.5	25	76	24.98	1.28	24.12	24.21	24.31	24.98	26.62	27.09	27.49
D31	9.5	10	9	10.3	...	11	8.5	10		75	9.61	0.73	9.12	9.17	9.23	9.61	10.55	10.81	11.05
D32	171	184	171	175	...	174	165	168		75	172.53	6.88	167.89	168.42	168.92	172.53	181.35	183.85	186.02
D33	89	93	92	84.6	...	93	86	91		75	89.66	3.7	87.16	87.45	87.72	89.66	94.4	95.75	96.92
D34	198	213	201	180.3	...	200	218	189	208	76	203.66	8.99	197.6	198.29	198.95	203.66	215.18	218.45	221.29
D35	120	123	120	129.6	...	115	126			74	124.72	6.6	120.27	120.77	121.26	124.72	133.18	135.58	137.66
D36	69	70	66	71	...	66	74.2	63	69	76	71.14	5.39	67.5	67.92	68.31	71.14	78.05	80.01	81.71

4.2.5 The bridge control console design

Based on the results of the percentile determination that has been done in the previous section, in this section, Bridge Control Console was designed. The Bridge Control Console design was made by using an ergonomic approach considering the anthropometric data of the Indonesian people and combined with the real constants in the "Guidance Notes on Ergonomic Design of Navigation Bridges". Below is shown flowchart of the process of making the Bridge Control Console design.

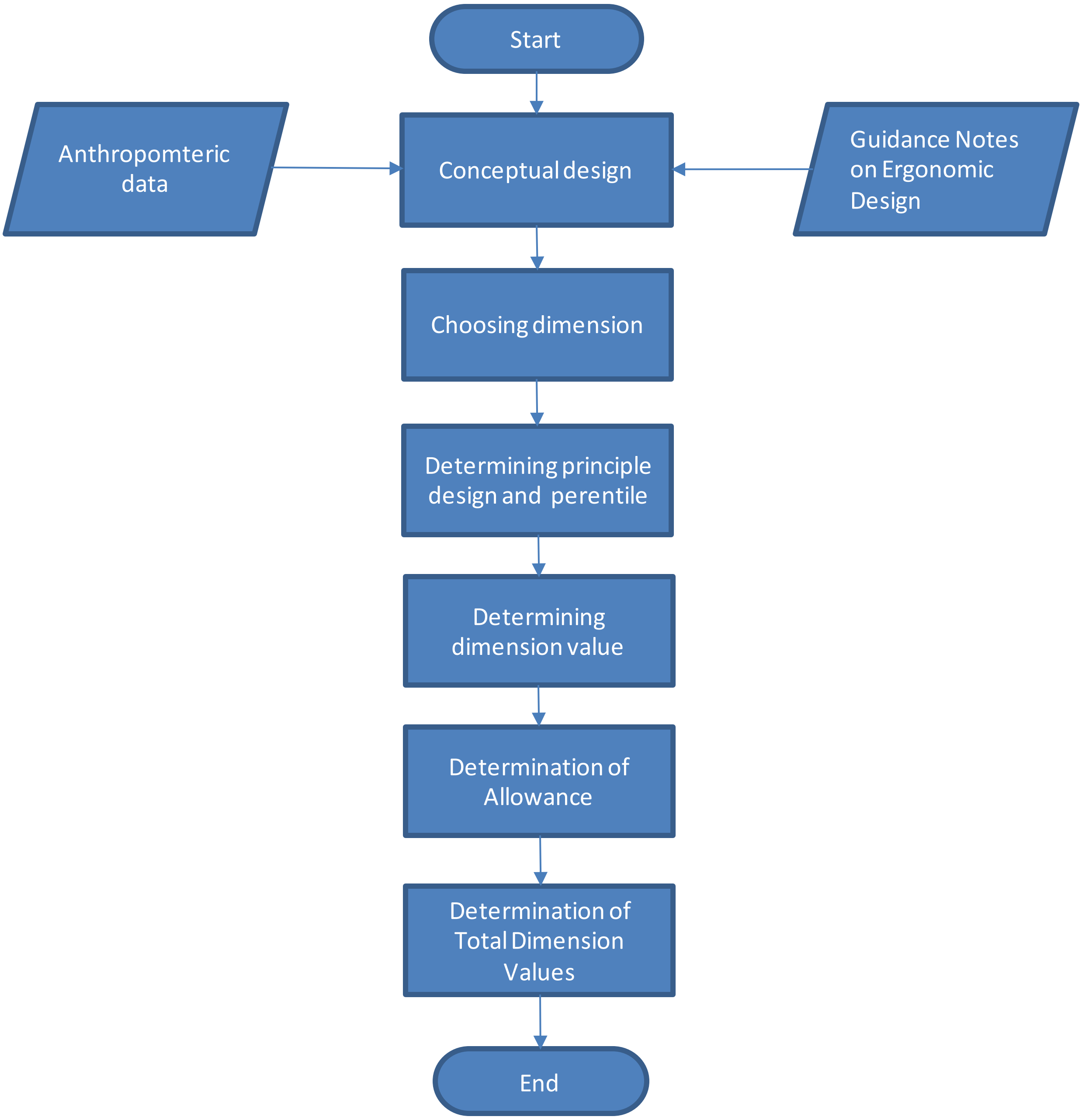

Figure 4.60 The Flowchart of Design Steps

In this research, the design concept of Bridge Control Console was made by considering two aspects of operator work those are the comfort during the standing and the sitting. Additionally, the designs are made is taking into account of the anthropometry of the body with a lower percentile value (27.5% of the Indonesian population or 2.5% of the estimated TNI population) and upper percentile value (97.5%). Based on these aspects, the designs expected to have high flexibility to maintain the operator comfort level while working. In this research, the Bridge Control Console design was divided into two major parts namely the Bridge Control Console design and chair design. The explaination for each of the concept design in this research is as follow.

4.2.5.1 2 Dimensional bridge control console design - standing working position

To maintain the comfort level of the operators while working to operate the Landing Ship Tank on standing position with different body height dimensions among operators, in this research the concept of Bridge Control Console created is adjustability or can be adjusted when the operator uses it. With this idea, operators can be comfortable when running their activities. Here is shown a 2-dimensional image of Bridge Control Console design at standing working position.

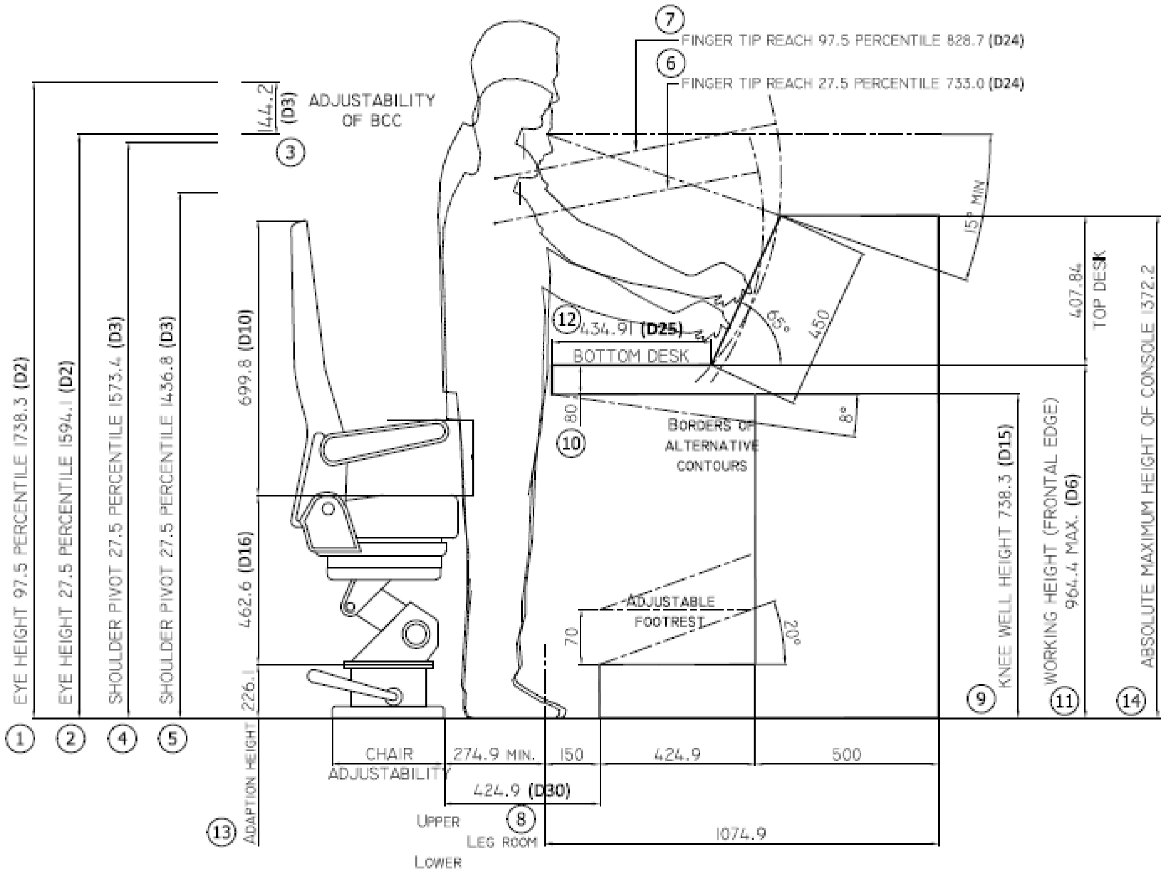

Figure 4.61 The Dimensional Bridge Control Console Design - Standing Working Position (Workstation 1 and 3)

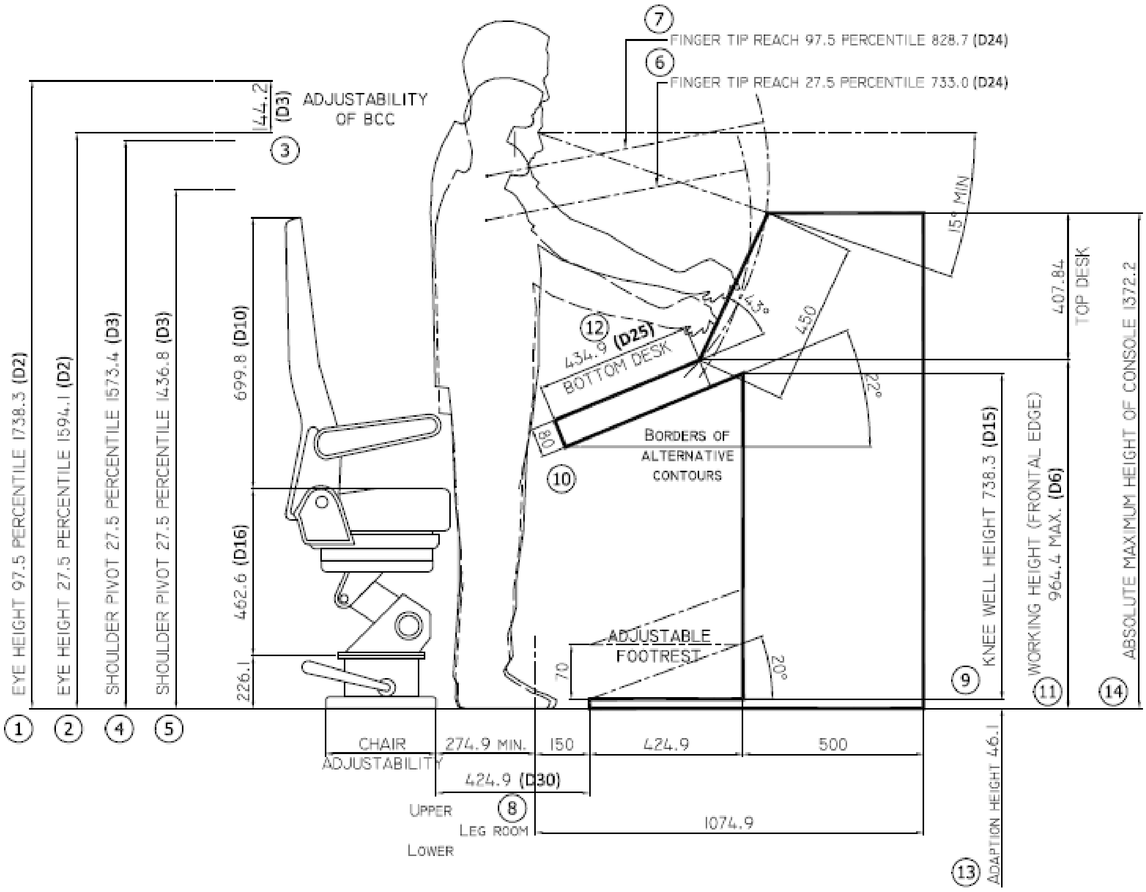

Figure 4.62 The Dimensional Bridge Control Console Design - Standing Working Position (Workstation 2)

The Bridge Control Console designed in this research has advantages that can be used comfortably through the concept of adjustability that accommodates the height of the body dimension that is on the lower percentile value (27.5%) to the dimension that is on the upper percentile value (97.5%) of the Indonesian population. The operator can adjust the height of the Bridge Control Console to match the anthropometry of his body. With this design, the comfort level of the operator will be well preserved. The table below showsdescription of each dimension used to design the Bridge Control Console to accommodate the various dimensions of the body when standing. Bridge Control Console is divided into three workstations where each operator in the three workstations can adjust the height of Bridge Control Console as desired.

Table 4.11 The Explanation of 2 Dimensional Bridge Control Console Design - Standing Working Position

Design Code	No	Design	Dimension	Description	Avg (cm)	Stdev (cm)	Design principle	Percentile (%)	Percentile value (%)	Allowance (cm)	Total (cm)	Note
A	1	Angle of eye maximum height	D2	The height of eye	156.78	5.64	Minimum	97.5	167.83	6	173.83	Using minimum percentile so that tall people (97.5%) can easily operate on standing position
	2	Angle of eye maximum height	D2	The height of eye	156.78	5.64	Maximum	27.5	153.41	6	159.41	Using maximum percentile so that short people (27.5%) can easily operate on standing position
	3	Adjustability of Bridge Control Console	D2	Range of dimension D2 Min – Max	-	-	-	-	14.42	0	14.42	Obtained from the difference
B	4	Range of fingers to the top desk	D3	The height of shoulder	140.87	5.34	Minimum	97.5	151.34	6	157.34	6 cm thick allowance for shoe
	5	Range of Fingers to the top desk	D3	The height of shoulder	140.87	5.34	Maximum	27.5	137.68	6	143.68	6 cm thick allowance for shoe
	6	Range of Fingers to the top desk	D24	The length of the range of hands forward	75.54	3.74	Maximum	27.5	73.3	0	73.3	

<table>
<tr><th>Design Code</th><th>No</th><th>Design</th><th>Dimension</th><th>Description</th><th>Avg (cm)</th><th>Stdev (cm)</th><th>Design principle</th><th>Percentile (%)</th><th>Percentile value (%)</th><th>Allowance (cm)</th><th>Total (cm)</th><th>Note</th></tr>
<tr><td></td><td>7</td><td>Range of Fingers to the equipment to the top desk</td><td>D24</td><td>The length of the range of hands forward</td><td>75.54</td><td>3.74</td><td>Minimum</td><td>97.5</td><td>82.87</td><td>0</td><td>82.87</td><td></td></tr>
<tr><td>C</td><td>8</td><td>Legroom for standing position</td><td>D30</td><td>The length of feet</td><td>24.98</td><td>1.28</td><td>Minimum</td><td>97.5</td><td>27.49</td><td>15</td><td>42.49</td><td>Allowance for the length and space for feet placement. Some of the allowance will be adjusted by adjustable chair (max 7.5 cm forward)</td></tr>
<tr><td rowspan="3">D</td><td rowspan="3">9</td><td rowspan="3">Space for knee</td><td rowspan="3">D15</td><td rowspan="3">The height of knee</td><td rowspan="3">51.89</td><td rowspan="3">2.52</td><td rowspan="3">Minimum</td><td rowspan="3">97.5</td><td rowspan="3">56.83</td><td>6</td><td rowspan="3">73.83</td><td>6 cm allowance for the thick of shoe</td></tr>
<tr><td>7</td><td>Allowance 7 cm for maximum height of adjustable footrest</td></tr>
<tr><td>4</td><td>Allowance 4 cm for empty space so that the operator's knee does not in contact the Bridge Control Console when the operator removes the leg from the Bridge</td></tr>
</table>

Design Code	No	Design	Dimension	Description	Avg (cm)	Stdev (cm)	Design principle	Percentile (%)	Percentile value (%)	Allowance (cm)	Total (cm)	Note
												Control Console
E	10	The thickness of bottom desk	-	-	-	-	-	-	-	8	8	Referring to Guidance notes on Ergonomic Design of Navigation Bridges
F	11	Maximum height of bottom desk	D6	The height of bone segment	74.8	7.98	Minimum	97.5	90.44	6	96.44	6 cm thick allowance for shoes
G	12	Width of bottom desk	D25	The length of shoulder-grip hand forward	65.46	5.57	Maximum	27.5	43.49	0	43.49	The width of bottom desk is determined by 70% (estimated position of the hand being bent) and is included between the front side of the seat and the front side of the table
H	13	Adaptation Height	-	-	-	-	-	-	-	-	22.61	Adaptation Height = D6 - D15
I	14	Absolute Height of Console	-	-	-	-	-	-	-	-	137.22	D6 + Top desk (40. 78 cm)

Explanation :

A. The angle of eye maximum height

Range value of the adjustability of the Bridge Control Console was determined by finding the difference of the height of eye (D2) between the maximum design principle (27.5th percentile) with the minimum design principle (97.5th percentile). The angle of the eye maximum height of the Bridge Control Console wass made to meet the needs of the operator in the lower percentile value (25$^{\%}$). Therefore the value is 159.41 cm. To meet the needs of operators with the height of body more than 25th percentile, it uses the concept of the Bridge Control Console with a maximum range of adjustability up and down is 14.42 cm. The range is obtained from the total of upper percentile value (97.5%) and lower percentile value (27.5%), where the value of both percentiles were obtained already considering the allowance of the addition of the height of body because of the use of shoe. Adjustability concept is made to keep the angle of the eye against the height of the toptip of the Bridge Control Console that is seen to form a 15º angle.

B. Finger range to Top Desk

The reach of the fingers was used to determine the maximum reach of the finger to the equipment on the top desk of Bridge Control Console (D24). In this research, the design made by using maximum design principle (27.5th percentile) to ensure people with lower percentile value (27.5%) can reach all the equipment in the top desk at the time of doing standing working position. Therefore, the width of the end of the Bridge Control Console (the area closest to the operator) to the upper (farthest) position is 73.3 cm.

C. The legroom for standing position

The legroom for standing position was determined by using minimum design principle (97.5th percentile) of the length of feet (D30). The upper percentile value (97.5%) was used to ensure that the operators with large feet can get enough space to work in a standing position. When the operator with the upper percentile is comfortable, the operator with the short feet will also be suitable doing the same job. In this research, the minimum legroom for standing position designed was found for 42.49 cm where the dimension already includes an allowance of 15 cm for additional leg length due to the use of shoe and also provides additional space so that the operator can adjust the leg position well and not in contact with the Bridge Control Console and chair. 7.5 cm of the total allowance given can be adjusted by changing the position of the front chair by 7.5 cm from the standard point.

D. The space for the knee

The space for the knee was determined to accommodate the needs of the operator while working in a sitting position. However, since space for the knee affects other dimensions to determine the different dimensions of the Bridge Control Console, the determination of the space for knee will be established. In this research, the space for knee was determined by using a minimum design principle (97.5th percentile) of the height of the knee (D15). The upper perecentile value (97.5%) is used to ensure the operators that have a higher knee height size can be comfortable while working in a sitting position. This design was made without forgetting the comfort level of the operator with a shorter knee height. To accommodate the comfort level of the two different types of operators, the space for the knee was made by providing the concept of footrest adjustability. The value of space for the knee was set at 73.83 cm which was obtained from the minimum design principle of the height of the knee 97.5th percentile) plus the allowance of the thickness of shoe (6 cm), allowance of footrest adjustability (7 cm), and allowance for empty space (4 cm) so that the operator's leg does not in contact with the bottom desk of the Bridge Control Console. The allowance value of 7 cm was obtained from the difference in the percentile value of the knee height [D15] (97.5%) with the lower percentile (27.5%), i.e., 58.63 - 50.38 = (~ 7cm)

E. The thickness of the Bottom Desk

The thickness of the bottom desk in this research was arranged according to the Guidance Notes on Ergonomic Design of Navigation Bridges (2003) which is 8 cm.

F. The Maximum Height of the Bottom Desk

The maximum height of the bottom desk was determined by using the minimum design principle (97.5th percentile) of the height of metacarpals (D6). It is arranged for 96.44 cm which is determined by using the upper percentile value (97.5%) that is 90.44 plus an allowance for the usage of the shoe which is 6 cm. The maximum height of the bottom desk was done by using the approachment of 97.5% to ensure that the operator has comfortable position. The value was set for the workstation 1 and 3 (left and right) [See Figure 4.60). The workstation 2 was designed in a titled position with an angle of about 22º and incline about 18 cm to facilitate the operator in operating the steering wheel so that the operator feels comfortable. Therefore, the bottom desk on workstation 2 of the Bridge Control Console's is slightly lower than the workstation 1 and 3 which is 78.44 cm.

G. The width of the Bottom Desk

The width of the bottom desk of Bridge Control Console was determined by using the length of shoulder-grip hand forward (D25) where it is estimated at 70% using maximum design principle (27.5^{th} percentile) which is 43.49 cm (70% x 62.13 cm). The value of 70% was determined because the operator's position of working is in a bent position and some hands are outside the bottom desk of Bridge Control Console.

H. Adaptation Height

Adaptation height is a dimension gained from the adjustment of other dimension values. The value of this dimension has no effect on operator comfort level. The dimension of adaptation height is obtained from the dimension value of the height of metacarpals minus the height of knee (D15) which is equal to 96.4473.83 = 22.61 cm for the workstation 1 and 3 and for the workstation 2 is 78.44 – 73.83 = 4.61 cm.

I. The Absolute Height of the Bridge Control Console

The absolute height of the Bridge Control Console console is derived from the height of the maximum height of the bottom desk plus the height of the top desk of the Bridge Control Console. The absolute height of Bridge Control Console is 137.22 cm

4.2.5.2 2 Dimensional design of bridge control console – sitting position & chair

To maintain the comfort level of the operator while working in sitting position, Bridge Control Console was designed with the concept of adjustability on footrest and chairs. The idea is expected to fulfill both the level of operator's needs of various body dimensions (lower and upper percentile). The following picture shows a 2-dimensional image of Bridge Control Console design when the operator is working in a sitting position and the design of the chair.

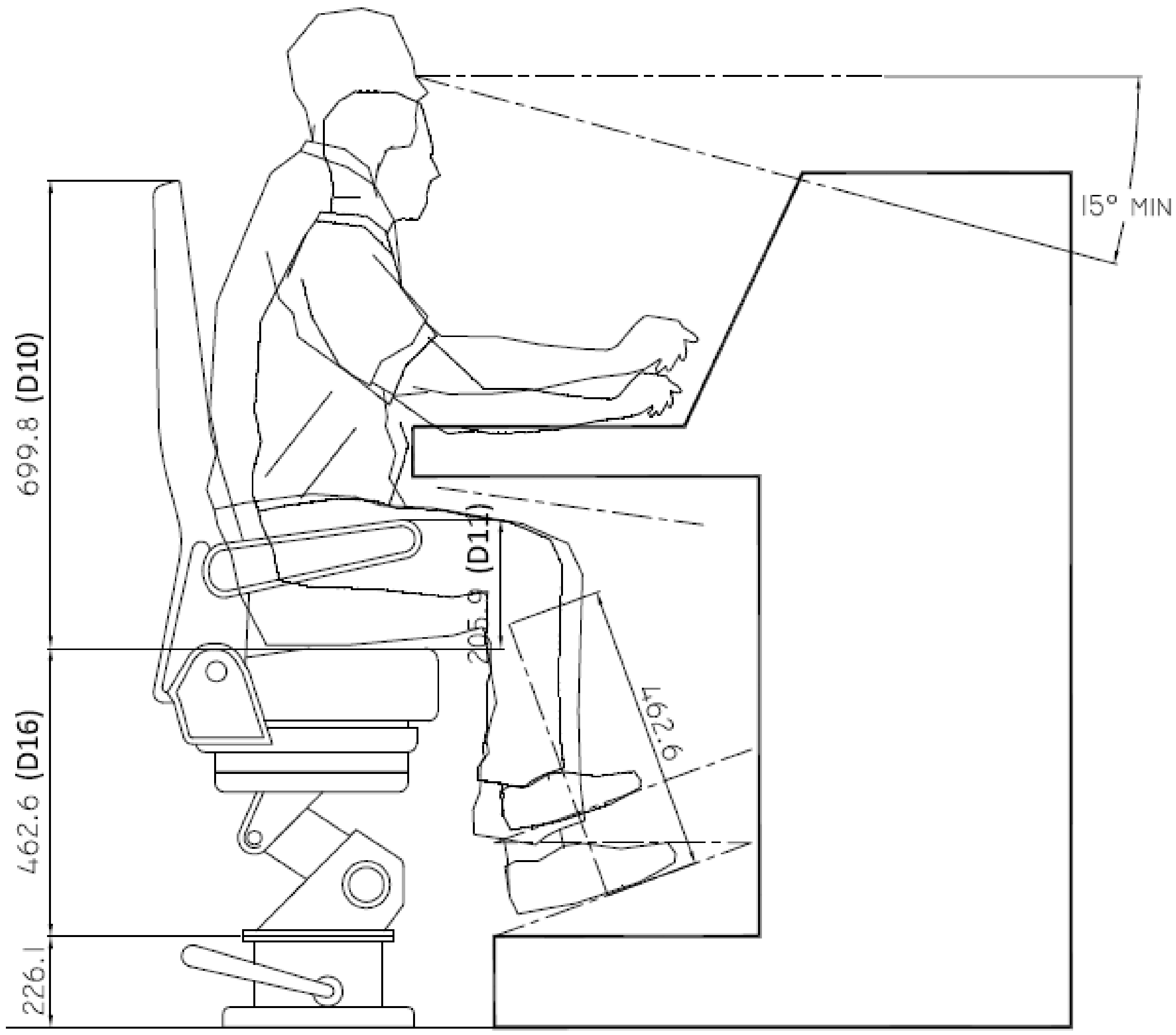

Figure 4.63 2 Dimensional Bridge Control Console Design – Sitting Working Position

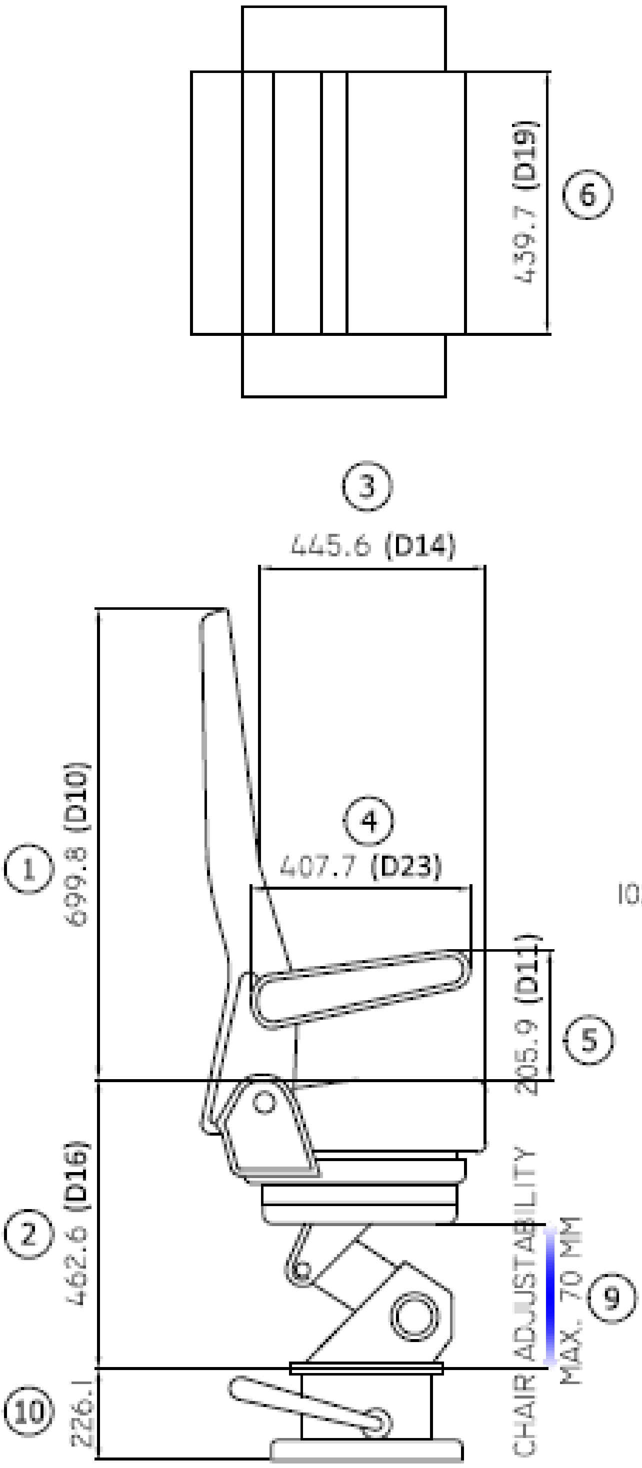

Figure 4.64 The Dimensional Design of the Chair

To keep the operator's convenience in working, the chair is also designed with adjustability in accordance to the anthropometry of the user's body, especially the dimension of the height to the footrest. Here is an explanation of each dimension of Bridge Control Console for sitting position and chair design obtained from an ergonomic analysis by considering the anthropometry of the body.

The following table shows the dimensions obtained to accommodate the operator comfort level while working in a sitting position.

Table 4.12 The Explanation of 2 Dimensional Bridge Control Console Design - Sitting Position & Chair

Design Code	No	Design	Dimension	Description	Avg (cm)	Stdev (cm)	Design principle	Percentile (%)	Percentile value (%)	Allowance (cm)	Total (cm)	Note
A	1	The height of backrest	D10	The height of shoulder in sitting position	60.65	4.25	Minimum	97.5	68.98	1	69.98	1 cm thick allowance for clothes
B	2	The height of cushion to the footrest	D16	The height of popliteal	41.65	2.33	Maximum	27.5	40.26	6	46.26	6 cm thick allowance for shoes
C	3	The length of the cushion	D14	The length of popliteal	46.33	4.64	Maximum	27.5	43.56	1	44.56	1 cm thick allowance for clothes
D	4	The length of the armrest	D23	The length of forearm	43.53	4.61	Minimum	27.5	40.77	0	40.77	-
E	5	The height of the armrest	D11	The height of elbow in sitting position	22.56	3.29	Maximum	27.5	20.59	0	20.59	-
F	6	The width of the cushion	D19	The width of hip	33.13	4.51	Minimum	97.5	41.97	2	43.97	1 cm thick allowance for clothes (1 cm for each side)
G	7	The width of the armrest	D29	The width of hand	8.68	0.81	Min	97.5	10.27	0	10.27	-
H	8	The width of the backrest	D17	The width of the shoulder	42.19	2.71	Min	97.5	47.5	0	47.5	-

Design Code	No	Design	Dimension	Description	Avg (cm)	Stdev (cm)	Design principle	Percentile (%)	Percentile value (%)	Allowance (cm)	Total (cm)	Note
I	9	The Maximum height of the chair adjustment	-	-	-	-	-	-	0	7	7	The height of the chair is equal to the height of the adjustable footrest of 7 cm which is obtained from the height of knee 97.5th percentile minus 27.5th - percentile (56.83 - 50.38 = 6.45 cm = 7 cm)
J	10	The Adaptation Height (based on workstation 1 & 3)	-	-	-	-	-	-	-	-	22.61	Based on the calculations for the workstation 1 and 3, the adaptation height is 22.61 cm, while for the workstation 2 is 4.61 cm
K	11	The Space for the knee	D15	The height of the knee	51.89	2.52	Min	97.5	56.83	6	73.83	6 cm thick allowance for shoes

Design Code	No	Design	Dimension	Description	Avg (cm)	Stdev (cm)	Design principle	Percentile (%)	Percentile value (%)	Allowance (cm)	Total (cm)	Note
										7		7 cm allowance for the maximum height of adjustable footrest
										4		Allowance of 4 cm for empty space so that the operator's foot does not knock when the operator removes the foot from the workstation

Explanation :

A. The height of the backrest

The height of the backrest was designed with the minimum design principle (97.5th percentile) of the height of shoulder in sitting position (D10) so that an operator with higher shoulder stay comfortably. By using the value of 97.5%, the obtained value is 69.98 cm

B. The height of the cushion to the footrest

The height of the cushion to the footrest was designed with maximum design principle (27.5th percentile) of the height of popliteal (D16) and 6 cm allowance for addition due to use of the shoe. The operator with higher knee height size is accommodated with the adjustability concept. By using the value 97.5 %, the obtained value is 46.26 cm.

C. The length of the cushion

The length of the cushion was designed with maximum design principle (27.5th percentile) of the the length of popliteal (D14). So that the operators with shorter popliteal lengths stay comfortable. By using the value 27.5 %, the obtained value is 44.56 cm, include 1 cm allowance for clothes.

D. The length of the armrest

The length of the armrest was designed with the minimum design principle (97.5th percentile) of the of the length of forearm (D23) so that the operator with longer arm stay comfortable. By using the value 97.5 %, the obtained value is 40.77 cm.

E. The height of the armrest

The height of the armrest was designed with the maximum design principle (27.5th percentile) of the of the of the height of elbow in sitting position (D11) so that the operator with shorter arm stay comfortable. By using the value 97.5%, the obtained value is 20.59 cm.

F. The width of the the cushion

The width of the cushion was designed with the minimum design principle (97.5th percentile) of the the width of the hip (D19) so that the operator with wider hip stay comfortable. By using the value 97.5 %, the obtained value is 43.97 cm, include 2 cm allowance for clothes on the right and left side.

G. The width of the armrest

The width of the armrest was designed with the minimum design principle (97.5th percentile) of the of the width of hand (D29) so that the operator with wider arm stay comfortable. By using the value 97.5%, the obtained value is 10.27 cm.

H. The width of the backrest

The width of the backrest was designed with the minimum design principle (97.5th percentile) of the width of shoulder (D17) so that the operator with wider shoulder stay comfortable. By using the value 97.5%, the obtained value is 47.50 cm.

I. The Maximum height of chair adjustment

The maximum height of chair adjustment is equal to the height of the footrest adjustment which is 7 cm.

J. The Adaptation Height

Based on the calculation results for the workstation 1 and 3, the adaptation height is 22.61 cm, while for the workstation 2 is 4.61 cm

K. The space for the knee

The space for the knee is designed with the concept of the footrest adjustability to accommodate operators with various size of the body. The value of space for the knee based on the calculation including the allowance is 73.83 cm.

4.2.5.3 3 Dimensional design

The 3-dimensional design is made with the reference to the dimensions specified in the 2-dimensional design of Bridge Control Console – standing position, sitting position, and chair design.

Here is shown the 3D design drawings developed in this research.

Figure 4.65 3 Dimensional Design of the Bridge Control Console – Top View

Figure 4.66 3 Dimensional Design of the Bridge Control Console - Front View (Exclude Chairs)

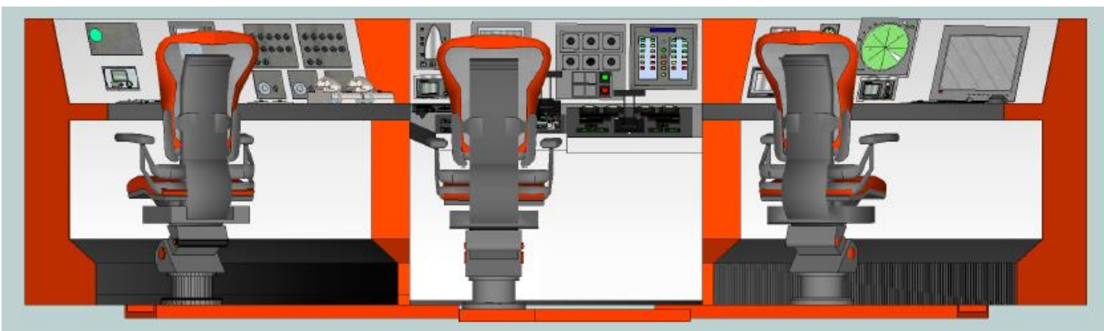

Figure 4.67 3 Dimensional Design of the Bridge Control Console - Front View (Exclude Chairs)

Figure 4.68 3 Dimensional Design of the Bridge Control Console

The dimension of the Bridge Control Console developed in this research was considered to be able to meet the comfort level of operators in working both in standing and sitting position because the design was developed by learning the aspects of ergonomics through a combination of the use of anthropometry data of Indonesian people with guidance notes on ergonomic design of navigation bridges. In addition, through the concept of adjustability on the Bridge Control Console and chair (adjustable and can move horizontally), the operators can easily adjust the position according to their needs.

4.2.6 The Bridge Control Console Design Validation

The Bridge Control Console design validation process was done by comparing several body dimensions between the data used in this research with the anthropometric data used in the "Guidance Notes on Ergonomic Design of Navigation Bridge". The anthropometric data used in this research is TNI anthropometry data approached from Indonesian anthropometry data, while the data used in Guidance Notes is anthropometric data of Americans. Here is a recap of the comparisons of body dimension data used.

Table 4.13 Comparison of Anthropometry Dimensions

No	Dimension	Description.	BCC	ABS	Gap (BCC - ABS)
1	D1	The height of body	168.7	175.58	-6.88

No	Dimension	Description.	BCC	ABS	Gap (BCC - ABS)
2	D2	The height of eye	156.8	163.39	-6.59
3	D3	The height of shoulder	140.9	144.25	-3.35
4	D5	The height of hip	96.92	107.25	-10.33
5	D6	The height of metacarpals	74.8	88.74	-13.94
6	D8	The height of body in sitting position	88.9	91.39	-2.49
7	D9	The height of eye in sitting position	78.28	79.2	-0.92
8	D10	The height of shoulder in sitting position	60.65	59.78	0.87
9	D11	The height of elbow in sitting position	22.56	23.06	-0.5
10	D13	The length of knee	57.17	61.64	-4.47
11	D14	The length of popliteal	46.33	50.04	-3.71
12	D15	The height of knee	51.89	55.88	-3.99
13	D22	The length of upper arm	36.01	36.9	-0.89
14	D23	The length of forearm	43.53	36	7.53
15	D25	The length of shoulder-grip hand forward	65.46	75.07	-9.61
16	D28	The length of hand	18.71	19.38	-0.67
17	D32	The length of the arm stretch to the side	172.5	182.31	-9.81

No	Dimension	Description.	BCC	ABS	Gap (BCC - ABS)
18	D35	The height of hand grip up in a sitting position	124.7	130.98	-6.28

Source : Gordon, Claire C. et. al. 1988 (American Anthropometry Data)

Note :

BCC = The Bridge Control Console designed in this research

ABS = American Bureau Shipping (Guidance Notes on Ergonomic Design of Navigation Bridge)

Dimension data that is compared only to body dimensions in which data is present. The comparable value is the average value of the dimension

Based on the comparison table of anthropometric dimensions used in this research and ABS guidance, it can be concluded that generally, the body dimensions of Indonesian people are relatively smaller compared to Americans. Therefore, this condition can be used as a reference in the design validation process. Logically, the dimensions of Bridge Control Console in this research should be smaller than the Bridge Control Console dimension in ABS guidance. The following table shows the comparison of the dimensions of Bridge Control Console designed in this research with Bridge Control Console in ABS guidance.

Table 4.14 Comparison of Bridge Control Console Dimensions

Design Code	No	Design	Dimension	Description	BCC (cm)	ABS (cm)	Gap (cm)	Notes
A	1	The Maximum height of Bridge Control Console	D2	The height of eye	173.83	178	-4.17	-
	2	The Maximum height of Bridge Control Console	D2	The height of eye	159.41	150	9.41	The percentile used is different (ABS : 2.5%, BCC : 27.5%). In BCC there is a 6cm thickness allowance of shoe
	3	The Adjustability of Bridge Control Console	D2	Range of dimension D2 Min – Max	14.43	N/A	14.43	The Bridge Control Console of ABS is not adjustable
B	4	The range of the fingers to the top desk	D3	The height of shoulder	157.34	150	7.34	-

Design Code	No	Design	Dimension	Description	BCC (cm)	ABS (cm)	Gap (cm)	Notes
	5	The range of the Fingers to the top desk	D3	The height of shoulder	143.68	126	17.68	The percentile used is different (ABS : 2.5%, BCC : 27.5%). In BCC there is a 6 cm thickness allowance of shoe
	6	The range of Fingers to the top desk	D24	The length of the range of hands forward	73.3	67	6.3	The percentile used is different (ABS : 2.5%, BCC : 27.5%).
	7	The range of Fingers to the top desk	D24	The length of the range of hands forward	82.87	78	4.87	-
C	8	The leg room for standing position	D30	The length of feet	42.49	45	-2.51	-
D	9	The Space for knee	D15	The height of knee	73.83	68	5.83	In BCC, there is a 6 cm thickness allowance of shoe + space adjustment (4 cm)
E	10	The thickness of the bottom desk equipment	-	-	8	8	0	-
F	11	The maximum height of bottom desk equipment	D6	The height of metacarpals	96.44	96	0.44	In BCC, there is 6 cm thickness allowance of shoe
G	12	The width of bottom desk equipment	D25	The length of shoulder-grip hand forward	43.49	35	8.49	The value is approximated from the 70% dimension of the length of the shoulder-grip hand forward
H	13	The Adaptation Height	-	-	22.61	20	2.61	-

Design Code	No	Design	Dimension	Description	BCC (cm)	ABS (cm)	Gap (cm)	Notes
I	-	The Absolute maximum Height of BCC	-	-	137.22	135	2.22	-

Based on the comparison, the dimension of Bridge Control Console in this research is not too much different with the dimension of Bridge Control Console on ABS guidance. There are several dimensional sections in this research that are bigger than Bridge Control Console on ABS guidance, but the difference is not too far away. This condition occurs because in this research there is some allowance that is considered including the shoe thickness, space for legroom, and so forth. Looking at the anthropometric data of American people that are relatively larger than the anthropometry of Indonesian people, the logical dimensions of the Bridge Control Console in this research should be smaller than the dimensions in the ABS guidance. As for several dimensions in this research that the value is greater, it is caused by the determination of allowance is determined and indeed the anthropometry data dimension is a greater value than ABS guidance. The dimensions of Bridge Control Console specified in this research can be said to be valid.

4.2.6 Display arrangement

According to SOLAS Chapter V Regulation 15, The bridge shall be designed and arranged with the aim of:

1. Facilitating the tasks to be performed by the bridge team and the pilot in making full appraisal of the situation and in navigating the ship safely under all operational conditions;
2. Promoting effective and safe bridge resource management;
3. Enabling the bridge team and the pilot to have convenient and continuous access to essential information which is presented in a clear and unambiguous manner, using standardized symbols and coding systems for controls and displays;
4. Indicating the operational status of automated functions and integrated components, systems and/or sub-systems;
5. Allowing for expeditious, continuous and effective information processing and decision-making by the bridge team and the pilot;
6. Preventing or minimizing excessive or unnecessary work and any conditions or distractions on the bridge which may cause fatigue or interfere with the vigilance of the bridge team and the pilot; and
7. Minimizing the risk of human error and detecting such error if it occurs, through monitoring and alarm systems, in time for the bridge team and the pilot to take appropriate action.

According to SOLAS Chapter V regulation 19 and 22, the design of bridges is governed by :

1. The functions and related tasks to be carried out on the bridge, systems used and methods of task performance
2. The range, layout and location of workstations required for performance of bridge functions
3. The fields of vision required for visual observations from each of the workstations

4. Composition of the bridge team and the procedures required for safe operations under all identified conditions
5. The type and range of equipment to be provided for performance of the tasks at the individual workstations and elsewhere on the bridge

According to Guidance Notes on Ergonomic Design of Navigation Bridges (2003), to reduce the need of the number of the manpower (operators) to operate the Bridge Control Console, it can be done by arranging the placement of equipment (display arrangement) well so that the activity of moving operator from one workstation to the workstation can be reduced. The equipment placement settings are based on the frequency of the use of the equipment, the level of importance and the order of use of the equipment.

Concerning the information, the compilation of existing equipment at Bridges Control Console in this study was prepared by using the approach. List and number of equipment that exist in this research is the same as the condition in company observation, without any reduction or addition of equipment

The following table is the result of the grouping equipment of Bridge Control Console that has been done.

Table 4.15 Display Arrangement Bridge Control Console

Area	**No Equipment**	**Description**	**Function**
Workstation 1	I26	VDR	Indicator / Monitoring
	I25	CCTV	Indicator / Monitoring
	C9	Navtex	Communicating
	N5	Echo Sounder	Navigating
	N29	Search Light	Navigating
	N32	Bridge Lighting Panel	Navigating
	C13	Horn	Communicating
	N22	Go Stop Lamp	Navigating
	C10	Telephone	Communicating
Workstation 2	N1	GPS	Navigating
	N30	Navigation Light Panel	Navigating
	M17	NFU Control	Manoeuvring
	I28	Engine Display	Indicator / Monitoring
	C27	Telegraph	Communicating
	M21	Emergency Stop	Manoeuvring
	M31	SGR Control Panel	Manoeuvring
	C12	Talk Back	Communicating
	M16	NFU Tiller	Manoeuvring
	I24	Alarm Signal Unit	Indicator / Monitoring
	C11	Intercom	Communicating
	M15	Rudder Angle Indicator	Manoeuvring
	M18	Steering Wheel	Manoeuvring
	M19	Steering Mode Selector	Manoeuvring
	M20	Steering Mode Indicator	Manoeuvring
	M14	Propulsion Control	Manoeuvring

Area	No Equipment	Description	Function
Workstation 3	N6	Wind Direction	Navigating
	I23	Speed Log	Indicator / Monitoring
	N4	Magnetic Compass	Navigating
	N3	Steering Repeater Compass	Navigating
	T8	Radar	Traffic Surveillance
	T7	AIS	Traffic Surveillance
	N2	ECDIS	Navigating

Based on the result of grouping done, the majority of the most commonly used equipment is placed on workstation 2. Where in the workstation 2, there are important equipments that serve as navigating, and manoeuvering, and some communicating & indicator equipments that most frequently used. In addition, workstation 2 is the workstation that is closest to the standard operator position so that later, the operators will not be too often move to the other workstation side. Some important and often used equipments are placed on workstation 1 and 3, by the consideration of the location of the placement is still easy to see by the operator in the workstation 2, so that the operator in workstation 2 does not move in long distances. To maintain the flexibility of the operator's job, the operator chairs are made with the concept of rail so that the operator can adjust the position of the chair in accordance with the equipment to be controlled. The length dimensions of each workstation are determined based on the dimensions of the equipment in it by considering the design aesthetics so that the Bridge Control Console designed has good appeal.

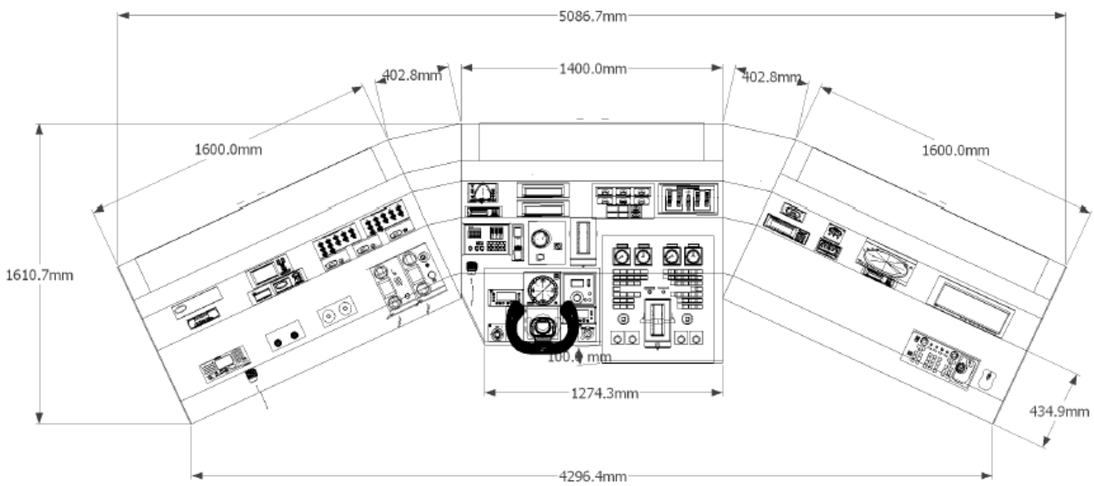

Figure 4.69 The 2 Dimensional Display Arrangement

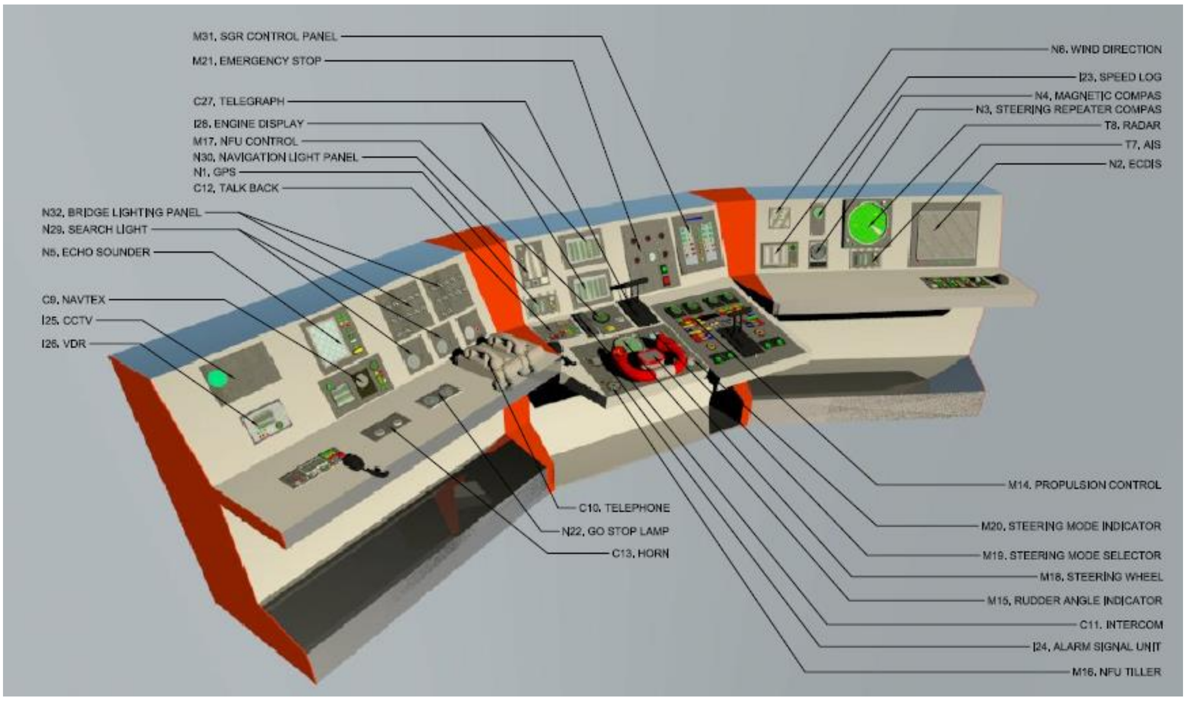

Figure 4.70 The 3 Dimensional Display Arrangement

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CHAPTER V
CONCLUSION & RECOMMENDATION

5.1 Conclusion

After the observation, data collecting, data processing and designing the Bridge Control Console in this research, it can be concluded that :

1. In designing a product, it is necessary to consider aspects of ergonomics into the design so that the developed product provides a good level of comfort to the operator so that the operator's working concentration is well maintained and the possibility of accident due to the human error can be eliminated
2. One of the ergonomic approaches to consider in a design is the anthropometric approach, but before anthropometry data is used, it is necessary to be tested to ensure that the data is valid. In this research, the Bridge Control Console is designed to meet the standards operators with 27.5th percentile. However, for the operators with upper percentile to stay comfortable when running the activity, Bridge Control Console is designed through the concept of adjustability on the Bridge Control Console and chair. With that concept, the Bridge Control Console designed will have high flexibility to meet the comfort level of operators with different dimensions, both incoming dimensions in the lower percentile (27.5%) and upper percentile (97.5%). To accommodate the standing working position, (27.5th percentile), the height of Bridge Control Console should not exceed 137.23 cm. The adjustability of the Bridge Control Console is set at 14.43 cm which is obtained from the range of 97.5% and 27.5% percentile of the height of eye. Meanwhile, to maintain the comfort level of the operator when working in a sitting position, the adjustability of chair and footrest is 7 cm.

5.2 Recommendation

1. In designing Bridge Control Console, shipbuilding Industry needs to conduct in-depth study by considering aspects of ergonomic aspects so that user (operator) feel comfortable and safe when using the product
2. This research may be served as a reference for designing similar products or other products using the same data and method.

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